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1. war gases ⑪ pacific war.
2. bacon ⑫ dried milk
3. blood storage
4. crop destruction
5. shell eggs ⑬ meat dehydration
6. nutrition
7. shipping shortages
8. butanediol production
9. wheat fractionation
10. world food supplies.

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WAR HISTORY
OF
DIVISION OF BIOLOGY

OTTAWA

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HISTORY OF THE WARTIME ACTIVITIES
OF THE DIVISION OF APPLIED BIOLOGY,
NATIONAL RESEARCH COUNCIL,
OTTAWA, CANADA

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HISTORY OF THE WARTIME ACTIVITIES OF THE DIVISION OF APPLIED BIOLOGY, NATIONAL RESEARCH COUNCIL, OTTAWA, CANADA

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A. INTRODUCTION

The urgency of war directs activity along the line of applications and development rather than toward fundamental contributions to knowledge. Biological research generally and the activities of the Division of Applied Biology in particular, have dealt largely with the 'defensive' type of problem, lacking the spectacular element implicit in developments of an 'offensive' character, the stimulating interest of fundamental work, or the hidden feeling that success would yield a secret weapon. The defensive type of problem must be anticipated if useful progress is to be made before the actual need arises. Such work inevitably contains some negative results. Certain problems were not foreseen, and others that were anticipated did not arise. Results applied in practice represent the real contribution. Since much of the work has now been published in about 100 papers, it seems best first to review the major problems in general terms, and then in succeeding sections to indicate more specifically how the various projects came to be undertaken, the results obtained, and their relation to the war effort. Hitherto unpublished work is treated in slightly greater detail.

In retrospect the Divisional activities during the war period can be divided into seven phases. The outlook was different during each period, resulting in a somewhat different type of problem having the greatest urgency. Each of these phases marks a period of initiation rather than termination, since the work undertaken at one stage was seldom complete before the next phase brought a new class of problem.

Several months of waiting - the period of Uncertainty - followed the first shock of war. The entire staff expected to receive instructions as to what they should do, and anxiously awaited requests to undertake urgent war research or to supply technical information in their specialized fields. Meanwhile the group associated with food research, on their own initiative. began a series of investigations on methods of preserving Canadian bacon, since this was one of the problems that arose during the last war with disastrous effects on the Canadian trade. Also, when Britain cancelled her imports of dressed poultry, Canada was threatened with a surplus. Early in 1940 the Department of Agriculture asked the Division to undertake work on the canning of poultry products. Since unique cold storage facilities were available in the food laboratories, a problem on the storage of liquid blood was referred to us by the Subcommittee on Blood Storage of the Associate Committee on Medical Research.

The second period, extending from Dunkerque to the invasion of Russia, was one of Anxiety. After the fall of France, the staff realized that they would have to assume leadership themselves and anticipate future needs. One of the first efforts in this direction was in the field of chemical warfare because of its direct relation to the war. The group concerned later became the nucleus of the Physiological Section of the Chemical Warfare Establishment. Greatly increased exports of shell eggs brought problems that had not been anticipated. When Britain lost her European sources of supply, she asked Canada for more shell eggs, and this brought a request from the Department of Agriculture, for assistance in solving preservation problems. The proposal of the British Ministry of Food that thiamin be added to Canadian export flour, initiated nutritional extensive. The Department of National Defence asked us to review the existing Army ration scale, and in doing this to seek the co-operation of other nutritional organizations. Later, a nutritional service laboratory was established in the Division to investigate numerous problems referred by the Standing Committee on Nutrition and to assess the value of foods offered for sale to the Department of Munitions and Supply. This work fully utilized the special training and experience of the statistical section.

A phase of Shipping Shortages, which extended through the Battle of the Atlantic, accentuated food storage and transport problems. When European sources of supply were cut off, more food had to be brought to Britain over greater distances. Shipping losses became serious and the resulting use of convoys slowed marine traffic. All of these factors put a tremendous strain on the carrying capacity of available cargo ships. The British required perishable food products in large volume and these demanded refrigerated shipping space. It became impossible to meet these demands without the introduction of emergency measures. Divisional engineers contributed to the solution of this problem by designing an emergency refrigeration unit to cool ordinary cargo holds, and other members of the staff worked on problems connected with dehydration of food.

Pearl Harbour introduced the fourth period, one of Strategic Shortages of certain raw materials. Loss of the Malayan rubber plantations and the inadequacy of our rubber stock-piles focussed attention on the possibility of using native-grown plants. This Division co-operated in an exhaustive investigation of the possibilities. It was evident, however, that synthetic rubber, based on butadiene, would have to meet the major war demands of the United Nations. Divisional workers undertook a large scale investigation on the possibility of producing intermediates for the production of

butadiene from agricultural crops. This programme led to the building of a pilot plant to investigate the commercial production of butanediol. Canada's domestic supplies of starch and sugar became exceedingly limited during this period and successful laboratory methods for obtaining high quality starch and starch-free gluten from patent flours were devised. Shortages of agar agar used as a jelling agent in food products led to a study on the extraction of gelose from Irish Moss, an Atlantic coast seaweed. The shortage of tin added impetus to the study of alternative methods for packaging perishable foods.

The year 1943 brought concern as to World Food Supplies and during this fifth phase food investigations assumed a new importance. While local shortages could be attributed to inadequate shipping, it became evident that world food supplies were perilously low. This consideration formed the background for the Hot Springs Conference where plans were formulated for the future. Moreover, the close of the war would bring the problem of feeding the populations of the liberated nations. The Combined Food Board undertook this problem. In 1943 they sent a mission to South America to see if additional foods, particularly animal proteins, could be procured there. The Director of the Division was invited to become a member of the British team on this mission. His part was concerned with the technical aspects of food concentration and reducing perishability to enable the foods to be stock-piled. Laboratory investigations included co-operative studies on both vegetable and animal oils, intensified work on the drying of eggs, and new investigations on dehydrated meat and milk.

The problem of fighting nature as well as the enemy introduced the sixth phase (Pacific War) late in 1943 when military activities in the South-West Pacific area had shown that supplies would have to be climate-proofed. Reports from Australian and American forces indicated that supplies were frequently arriving in the South-West Pacific in poor condition because of inadequate packing. Poor packaging resulted in excessive breakages during transport and losses under the primitive storage conditions available were enormous. Furthermore, the ravages of insects and fungi often rendered clothing and equipment useless within a few days. Facilities for extensive investigations were set up in the Division and work undertaken for all the Services. The work was given a high secrecy rating, and none of the results have been published to date (1945). The closest co-operation has been maintained with our Allies. About 135 secret reports have been prepared and distributed in Canada, the United States, and Britain. In the late summer of 1944, a member of the staff was invited to become a member

of the British Packaging Mission which examined the American methods of preservation, packaging and identification of materials. He was able to acquaint himself with the tropicalization work under way in the principal American laboratories and ordnance depots. From time to time, meetings have been attended in Washington and elsewhere with the object of keeping our investigators informed on the latest developments.

The seventh phase commenced with the end of the war in Europe since Divisional war investigations had then to be assessed in relation to the Pacific campaign, the feeding of a devastated Europe, and the national economy of the future.

EFFECT OF WAR ON THE GROWTH OF THE DIVISION

The Division of Applied Biology was established in a small way in Ottawa in 1932 and its natural growth was hampered by the depression. To do certain pressing jobs several Associate Committees in the biological field seconded staff to these laboratories. In 1939 the Division had the following establishment: 22 staff positions of which 7 were filled by permanent and the remainder by term appointees, and 15 committee employees, making a total staff of 37.

During 1940 and 1941--which have been termed the periods of "uncertainty" and "anxiety"--little change took place in the total number of the staff, although there were some losses to the Services. By late 1941, shipping shortages had resulted in numerous problems being referred to us. In a short time almost 100% of the staff were fully occupied with war work. In 1942, with the beginning of the phase of strategic shortages, the search for substitute materials to replace rubber, agar, and tin inevitably resulted in large expansion in Divisional personnel and equipment. Several pilot plants were built and staffed.

As with other divisions of the Council, additional staff requirements were met by war appointments. Upwards of 200 war appointments were made during the period 1940-1945.

During the period of strategic shortages, the possibility of utilizing agricultural wastes and surpluses for the production of war chemicals was carefully considered. Since such investigational effort would also be particularly valuable in the post-war era, the establishment of 116 new positions has been approved for this purpose. Of these, 53 were assigned to the Divisional laboratories in Ottawa and 63 were given to a new Prairie Regional Laboratory associated with this Division . When the war ended, the Division had 206 positions of which 6

were filled by permanent, 46 by term, 4 by Associate Committee employees, and 64 by war appointees; and the rest remained unfilled.

DISTRIBUTION OF INFORMATION TO INDUSTRY

To place the results of investigational work in the hands of industry as quickly as possible, the staff have been encouraged to present the results of their work in trade journals. Articles of this nature dealing with our war-time activities are listed at the end of this section.

DISTRIBUTION OF INFORMATION TO THE PUBLIC

One of the seven duties with which the Research Council was originally charged was the education of the public in regard to the importance and utility of applying the results of scientific and industrial research to production. In spite of pressing war duties the Division has not lost sight of this important aspect of the work. From time to time the Director and senior members of the staff have addressed public meetings on the work of the Division, and in addition a number of articles have been prepared for the popular press.

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B. PERIOD OF UNCERTAINTY

A feeling of uncertainty existed among many biological groups throughout the Commonwealth during the first few months of the war. All were awaiting direction but the expected instructions were not forthcoming. With hind-sight, of course, it is easy to see that the uncertainty concept was fundamentally wrong. Research programmes, even in an applied field, are seldom, if everm undertaken on specific instructions. The hard-pressed administrator may be the first to hear of really worth-while problems, but he frequently fails to recognize them as capable of scientific study, and even if he does, it still requires a technically trained man to reduce the problems to the specific terms necessary for laboratory investigation.

However, the first effort was to complete the peace-time problems on which the staff had been engaged. As a result, a spate of technical papers dealing with peace-time problems was published during 1940, and in dwindling numbers thereafter. Thus the decks were cleared for action.

BACON

Preservatives

For more than one hundred years the demands of the British people for bacon have been greater than the home production could supply, with imports reaching a peak of more than a billion pounds per annum in the 1930's. Canada has had a share in this huge market since 1870. By the turn of the century the growth of marine refrigeration gave impetus to the trade, and for the past forty years an average of about 17% of Britain's bacon imports have been obtained from Canada.

Prior to the war, Divisional investigators had been attempting to improve the quality of Canadian bacon. It was evident that Canada would be called upon to supply large quantities of bacon, and the investigators were in a position to anticipate problems peculiar to war-time.

Food transport problems had arisen in the last war when bacon had to be shipped in unrefrigerated space. Hard cures and borax had been used to avoid spoilage, but the eating quality of the product left much to be desired. Were such problems likely to recur? It seemed probable that they would. The effect on keeping quality of hard curing by noth wet and dry salting methods, and of treatment with borax, boric acid, acetylsalicylic acid and a mixture of benzoic and citric acids

was investigated on bacon sides and gammons stored at 16°C. for storage periods up to 60 days. In addition, tons of treated bacon were sent to Britain at the request of the British Ministry of Food. Of the methods studied for preventing spoilage, packing in a 13:3 salt-borax mixture was most effective - but was very detrimental to flavour quality because of the presence of excessive quantities of sodium chloride and undesirable dessication of the meat.

More information on meat preservatives was necessary and over 100 chemicals were tested extensively for their effectiveness in maintaining quality in bacon. Part of this work has already been published.

Briefly, chemical treatments were tested on bacon stored over a temperature range from 7° to 28°C. for one month. The relative suitability of the compounds was assessed by organoleptic examination. In later studies, quantitative surface bacterial counts were used to select the more effective materials.

Treatments found to retard both slime formation and mould growth included: magnesium benzoate with hydroxy acetic or citric acid; dimethylol urea; boro-benzoic acid; acetylsalicylic acid; and a few other materials and mixtures. Several treatments were relatively effective against bacteria but not against moulds, viz: magnesium benzoate; sodium benzoate with hydroxy acetic acid; benzoic or boric acid with hydroxy acetic acid; and pyruvic acid. A few of the treatments retarded mould growth, but had little or no effect on bacteria, and these included borax. While some of the better treatments offered distinct possibilities for extending the storage life, approximately doubling the possible holding or shipping period at a given temperature, none was entirely satisfactory.

Parallel investigations were made on the suitability of polyvinyl alcohols, dimethylol urea, commercial wax dispersions, carbon dioxide, sodium hydroxide, and a combined smoking and partial dessication treatment as preservatives for bacon.. Smoking and drying produced the best results, and except for a heavy mould growth, the bacon was in satisfactory condition after two months' storage at 60°F. Dimethylol urea was also effective, but nothing was known of its toxicity. None of the remaining treatments was suitable.

Smoked Bacon

Since it had been indicated that smoking prior to

shipment might contribute substantially to the keeping quality of bacon, this possibility was investigated in some detail.

Wiltshire bacon, cured in pickles of different compositions, was smoked after various maturation periods, and compared with corresponding unsmoked samples during subsequent storage at -9.4°C. Curing practices designed to obtain milder cures were only partly successful, but smoking always improved the keeping quality.

Smoking reduced the number of surface bacteria to approximately 1/10,000 of the number present before smoking and effictively retarded growth during storage. Fat of smoked bacon was much more resistant to development of rancidity than that of unsmoked bacon. The colour of smoked bacon was significantly lighter, but tended to darken more rapidly during storage. Flavour was superior in the smoked samples. Judging from the reduction in bacterial numbers, rate of bacterial growth, and rate of rancidity development, smoked bacon will keep about twice as long as unsmoked bacon under comparable conditions.

In further experiments, spoilage in the fat of smoked and unsmoked Wiltshire backs and gammons, stored at temperatures of -18° to +7°C. for about four months, was assessed by determinations of peroxide oxygen and free fatty acid contents. Smoked bacon can be stored satisfactorily for at least two months at freezer temperatures, whereas unsmoked bacon was usually rancid after one month.

Colour and colour stability measurements on the same samples showed that differences in brightness between bacon sides were appreciable. Decrease in brightness with time was evident after 70 days at 7°C., but not until after 98 days at freezer temperatures. Smoking increased brightness. Colour stability measurements on all samples showed that exposure caused a decrease in the proportion of red and an increase in green and green-blue.

After curing, a maturation period normally intervenes before the bacon is smoked, and the peace-time shipping period fulfilled this function. But if bacon were to be smoked in Canada, the effect of maturation had to be assessed. The criteria used consisted of flavour tests, determinations of surface bacterial growth, peroxide oxygen formation in the fat, and changes in colour and colour stability of the lean meat during storage at -1.1°C. subsequent to smoking. By all these criteria, bacon could have been smoked immediately after

curing if necessary. However, there was some indication that a maturation period of about 10 to 15 days was most suitable.

Defrosting Studies

The demand for bacon required that an increased amount be held in frozen storage from the period of peak production (winter season) to the period when hog receipts were limited (summer season). This brought a request from the Department of Agriculture that we undertake investigations on the defrosting of Wiltshire sides. Accordingly, frozen Wiltshire sides were defrosted at temperatures of 4.4°, 12.6° and 21.0°C. in water; curing pickle; brine of 5, 15 and 30% concentration; and in air of both high and low relative humidity. Thawing in air, brine, or water could be accomplished satisfactorily provided proper conditions were maintained and prolonged exposure avoided.

Standard Cure

Pre-war export curing practices in Canada had been designed for a 10-day voyage. The use of convoys extended this period to 20 days or more, with a corresponding decrease in quality upon arrival in Britain. This brought a request for harder cures (higher salt content) with the specific suggestion that this be obtained by longer curing periods. Our pre-war work had shown that, while curing periods used in different Canadian plants varied over 100%, the rate of up-take of salt was negligible after the first few days. Increased curing periods would therefore have been of little value and would have demanded additional curing facilities at a time when labour and materials were scarce and the bacon trade was expanding rapidly.

The Divisional investigators recommended standard curing practices in all plants by methods that would increase the salt content while decreasing the average time required for curing. With one minor exception these recommendations were accepted by industry and the Canadian and British officials concerned. While this wartime cure is somewhat too salty for the British palate, the reports received on this product under wartime conditions have been highly satisfactory.

Summary of Bacon Work

While some of the preservatives and processing methods studied, and smoking in particular, offered distinct possibilities for extending the storage life of bacon, none was assessed as adequate to permit shipments in unrefrigerated

space. The fact that refrigeration was the best preservative of all led naturally to engineering developments. Since these were linked with shipping shortages at a later stage of the war, their discussion is reserved for a later section.

CANNING INVESTIGATIONS

When Britain cancelled her imports of dressed poultry, Canada was threatened with a surplus, demanding valuable cold storage space for its preservation. Canning was an obvious relief measure, and at the request of the Department of Agriculture, work on canned poultry was undertaken early in 1940. The investigation was primarily a survey of initial product quality, processing procedures and methods of control, but the main object was to evolve an adequate specification which is now incorporated in the Meat and Canned Foods Act. Substantial assistance was also given to commercial operators.

A survey of commercial products indicated that quality improvement was possible in many brands of canned poultry while a lack of uniformity even within the same brand definitely pointed to a need for closer control in manufacture. Control measures were particularly necessary for such attributes as the weight of meat packed, the concentration of broth used, and the strength of jelly in the final product. An apparatus was developed for separating and checking the weights of meat and jelly in canned chicken, and an improved model of this device is in current use. A specific gravity chart was constructed for use in controlling broth concentration and a simple "jelly-strength tester" for commercial use was also devised.

Much of this work has not been published. Original specifications and control measures were subsequently improved by divisional personnel. These controls have been adequate during the war period, but recently the question of the moisture distribution in canned poultry has been reopened and is being investigated in some detail.

Laboratory investigations parallelled the work on control measures. Three classes of raw dressed chicken were processed by open and pressure precooking methods, and tested by a consumer taste panel. While the quality was dependent on efficient processing, canned chicken of good quality was obtained from even the lowest grade of raw dressed chicken, but the higher grades of raw material produced packs of superior quality. The results suggested that the quality of Canadian canned chicken could be improved by the uniform adoption of pressure precooking methods.

Vitamin C analysis indicated a measurable amount in canned chicken manufactured by improved methods. The amount was low in proportion to that found in other foods, but was sufficient to show that processes that minimize oxidation conserve the vitamin.

As the war progressed, the Allied Forces had need for 6-lb. containers of canned meat, that could be held at desert temperatures without deterioration. Prior to that time, most meats packed in containers of this size were subject to spoilage even at ordinary temperatures. Complete sterilization by current methods resulted in an overcooked, unacceptable product in which a considerable body of liquid separated and was lost as waste. This problem was investigated at the request and with the co-operation of Department of Agriculture officers and industrial firms. Suitable canning processes were worked out and assistance given to commercial firms. The vitamin content of canned pork was also studied.

BLOOD STORAGE

In the early part of the war, considerable interest was shown in the use of whole blood for transfusions. Since unique cold storage facilities were available in our food laboratories, an investigation to determine the best storage temperature for liquid blood was referred to us by the Subcommittee on Blood Storage of the Associate Committee on Medical Research. The first detrimental change that limited the storage period was the haemolysis of the red cells and measurement of this was used to assess the value of differential storage temperatures and treatments. At that time it was believed that blood kept at room temperature haemolyzed more rapidly than blood kept at lower temperatures, but experimental evidence was limited. In practice blood is usually stored at 0° to 6°C. The temperature range from -4° to 12.5°C. was studied in this investigation.

Supplies of human blood were donated by the staff and collected with the assistance of medical personnel from local hospitals. Although the primary object was a study of storage temperature, other conditions were also examined. The choice of conditions other than temperature was determined largely by an effort to approximate certain body conditions, i.e., the blood was kept in motion, free air was excluded, glucose added, and pressure applied.

Within the temperature range -4° to 12.5°C., minimum haemolysis occurred between 2.5° and 6°C. Cell volume

changes appeared to depend on storage temperature. Added glucose had the most marked inhibitory effect of any of the factors studied, and resulted in a pH drift to the acid side; the extent of this drift was governed by storage temperature. However, the behaviour of buffered blood mixtures indicated that the beneficial effect of glucose is only partially dependent on the pH changes produced. Excluding air and keeping the blood in slow motion also had highly significant effects in the reduction of haemolysis during the first four weeks in storage.

Other factors studied less extensively included differences between donors, dilutions, container sizes, and air pressures. Donor differences were important when the rate of haemolysis was low, but at higher rates they were masked by treatment effects. Dilution with isotonic solutions retarded haemolysis markedly. The size, shape or position of containers during storage had no demonstrable effect. The air pressure experiments indicated that storage at the normal blood pressure may be of some value in reducing haemolysis. Even under the best conditions, however, the blood could only be stored for about 4 weeks.

It was thought that the storage life of whole blood might reasonably be extended if it could be frozen without destroying the red blood cells. This possibility was explored by subjecting erythrocytes from sheep's blood to several pre-freezing treatments, freezing at various rates, and storing at various temperatures from -2° to -190°C. Minimum haemolysis generally occurred when the cells were suspended in 1 to 1.5 isotonic glucose and frozen extremely rapidly in liquid air. During subsequent storage about two-thirds of the cells survived 32 days' storage at -190°C., only about half survived at -78°C. and haemolysis was practically complete at higher temperatures. Cells held in both the supercooled and partly frozen condition at temperatures slightly below the freezing point showed that least haemolysis occurred in the supercooled samples. In the frozen samples the extent of haemolysis increased as the temperature decreased and was practically complete at -8°C. Although the results show that the formation of ice crystals is one of the primary causes of cell disintegration, differences between animals and other unknown factors also had a significant influence on the ability of the cells to withstand freezing. Cells dried from the frozen state, in vacuo, appeared normal, but always haemolyzed when liquids were added.

Some tests were made on dried blood preparations as a possible material for absorbing carbon monoxide in gas masks. Since the monoxide acts by rendering blood cells ineffective through formation of carbon-monoxide haemoglobin, it was thought that possibly the tables could be turned by tying up the monoxide with beef blood before the gas could enter the body. Unfortunately, the dried blood preparations were unable to absorb the carbon monoxide.

All of the above studies were terminated when serum came into general use. Subsequent assistance was given, however, on the development of containers for shipping whole blood from centres of collection to the laboratories engaged in serum separation and drying. Because of difficulties experienced by the Red Cross in sterilizing the assemblies used for drawing blood, studies on heat penetration into these assemblies were also made.

MINOR PROBLEMS

Although no spectacular requests for assistance were received during the period of Uncertainty, the Division was asked to undertake a number of minor war problems. These should not be overlooked and since much of this work has not been published it is described here for the first time.

Rhamus frangula for Fuze Powders

A few days after the declaration of War, Major General Lock of the British Purchasing Mission wrote to the President of the National Research Council inquiring if the tree Rhamus frangula L. grew in Canada. Charcoal from its wood is particularly valuable for the manufacture of a slow-burning fuze powder. Little was known about its distribution in Canada. The inquiry was referred to this Division and a survey was conducted covering Eastern Canada. The leading botanists and field naturalists in Ontario and Quebec were consulted with negative results with the exception of Mr. I. L. Connors of the Department of Agriculture, who informed us of two stands, one in the western suburbs of Ottawa and the other on the campus of the University of New Brunswick. Dr. H. A. Senn, also of the Department of Agriculture provided botanical information on the species and assisted in identifications. Information and samples were sent to Britain.

The matter was, therefore, considered closed and was not opened up again until after the fall of France.

The British were dependant upon the French for their supply of R. frangula and in August 1940 an urgent request came to the Council from the British Mission to produce some 12,000 lbs. of R. frangula charcoal during the following year. Since this was essentially a chemical engineering problem the work was undertaken by the Division of Chemistry.

The Division of Applied Biology again assisted in the hunt for additional stands of the shrub by carrying on a wide correspondence, and the largest stand found in Canada was located just outside the city of London. In addition arrangements were made with the owners of the Ottawa property for the Council to harvest that stand. The Ottawa and London stands together with some smaller ones were sufficient to take care of the entire war needs.

Mould Testing

Early in the war the Laundry and Textile Laboratory, Division of Chemistry, requested us to make mildew resistance tests on samples of chemically treated textiles. Later our facilities were used for the same purpose on a number of occasions by the Chemical Warfare Establishment and by other Government departments. During the course of the war some 1500 routine tests were made on various war materials.

Spatial Temperature Variations in Cold Stores

Problems met in cold storage practice within the Division prompted investigations in 1939 on spatial temperature variations. With the advent of war these studies were intensified since a shortage of cold storage space was anticipated. This condition would inevitably lead to increased quantities being stored in existing space with possible detrimental effects on air movement and spatial temperature variations. Temperature measurements were made in an experimental storage chamber under various vertical and horizontal air flows, with and without false loads with respect to heat and volume, and using various dunnage spacings between boxes and methods of directing air flow through the stack. Some 200 experiments included a total of about 50,000 temperature measurements all of which were subjected to statistical treatment. Part of this study has been published.

The presence of boxes was found to increase the spatial temperature variations in a refrigerated room. By forcing the air to pass through the stack, e.g., by blocking the aisles, such variations were reduced to approximately

the value prevailing in the empty room. Dunnage spacing also reduced temperature variations, but no significant difference was found between spacings varied from 5/16 in. to 2 in. Deductions made from these studies were of great value in devising the method of stowage used for the transport of bacon under emergency refrigeration, described later. Since this product generates little or no heat in transit, it was possible to stow a ton of bacon without the conventional dunnage spacing, in 55 cubic feet instead of the usual 70 cubic feet.

Calibration of Anemometer

Since a sensitive hot-wire anemometer was required for the above investigation, and in addition had other possible applications in connection with war problems, a suitable instrument was secured, calibrated, and its characteristics determined. A wet test meter was used to measure the air supplied to a small wind tunnel that could be adjusted to provide up-, down-, or side-draughts for the calibration of the instrument. The readings on this anemometer were independent of the direction of air flow and of the orientation of the instrument at velocities in excess of 10 ft. per min. At lower velocities separate curves were obtained for different instrument orientations and directions of air movement. Air flows as low as 1 ft. per min. can be estimated with useful accuracy provided the direction of air movement is known.

Freezing of Butter

War conditions required the storage of large quantities of butter and demanded the best possible practices. Some surface defects that could not be attributed to processing procedures were observed, and early in 1940 the Department of Agriculture requested a study on rates of cooling and freezing under different conditions.

It was found that a single box of butter in a room at 0°F. could be cooled from 52°F. to 10°F. in 54 hours. The box in the center of a cubical stack of 27 boxes required 320 hours to cool over the same temperature range. This indicated the importance of piling fresh receipts in an "open" pile, until they reach holding temperature, before stacking them in close piles for storage.

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C. PERIOD OF ANXIETY

Following Dunkerque, the staff immediately appealed to transfer to work likely to be of direct value in the war effort. It soon became evident that the workers themselves had to assume leadership and anticipate future needs. One of their earliest efforts in this direction was the search for biological indicators for war gases. During this period the Division was also requested to deal with a number of problems requiring specialized facilities, e.g., preservation of shell eggs, nutritional value of foodstuffs, fogging of tank windows, etc.

BIOLOGICAL INDICATORS FOR WAR GASES

Problems in the field of chemical warfare appeared to be most suited to the training of the staff, and it was felt that some experience along this line might be valuable. An exchange of visits between British and Canadian personnel interested in this field did much to give direction to the work. Most of the problems selected were of an elementary sort, designed largely for training purposes, although some were original. About a year later the Directorate of Chemical Warfare and Smokes was established under the National Defence Department. Laboratory space made available by the Division of Applied Biology, a senior investigator, and the personnel who had been trained in this work formed the nucleus of the physiological section of this establishment.

The employment of birds and other small animals as indicators for toxic gases, particularly in mines and indeed during the gas warfare of World War I, is well known. An initial experimental study was therefore undertaken with the object of accumulating some quantitative data on the reactions of mice.

Mice

An apparatus was devised for maintaining a specified concentration of toxic gas in an air stream flowing through the test chamber containing the mice. This procedure ensured an adequate supply of oxygen and avoided complication effects from the accumulation of carbon dioxide.

Experiments with a selected strain of mice indicated that 2 hr. exposure to concentration of mustard gas in excess of 0.230 mg. per litre would result in almost complete mortality within two to three days. The same length

of exposure to concentrations of less than 0.020 mg. per litre produced little or no lethal effect. Intermediate dosages resulted in more or less delayed mortality, the incidence of deaths with time suggesting two modes of action of this poison: the direct toxic effect of the mustard itself, and secondary infection or other impairment of vital organs.

The slope of the dosage--mortality curve tended to increase with time, indicating progressively more sensitive discrimination between dosages. Conversely, the median lethal dose diminished, until at ten days it could be estimated with some assurance to lie between 0.045 and 0.059 mg. per litre. The delayed incidence of mortality is clearly a factor which may have an important bearing on deductions from toxicity experiments with mustard gas.

Insects

On the basis of preliminary work, Drosophila melanogaster was chosen for further study, as it was more sensitive to the toxic materials used than either Musca domestica or Tribolium confusum. The mortality of Drosphila melanogaster following exposure to either a continuous flow or a static volume of air containing mustard, Lewisite or chloropicrin was determined by means of the special apparatus mentioned in the foregoing section. All three substances were lethal to the insect. Both mustard and Lewisite resulted in a significantly higher mortality under continuous flow than under static conditions.

Under conditions of continuous flow, flies subjected to mustard showed the same response immediately after 2 hr. exposure as did mice on the 6th day following similar exposure, but were somewhat less sensitive than mice in discriminating between concentrations. The susceptibility of Drosophila to chloropicrin was judged to be roughly the same as that of dogs and mice. For Lewisite, however, the insect proved to be about 75 times as sensitive as mice tested in the same apparatus, and reacted to concentrations of the order of 1 p.p.m. (part per million).

It was concluded that Drosophila showed promise as biological indicator of war gases, but as the results secured were markedly affected by temperature differences and also showed variability due to biological heterogeneity, further standardization would be required before this species could be used with predictable accuracy in routine tests.

Paramecia

Biological tests for toxicity of war gases made on laboratory animals are time-consuming, expensive and not always reliable due to great individual differences in reaction. It was necessary that the test organism be easily obtainable and inexpensive and that it show rapid reactions to a gas and give clear-cut symptoms of injury. Unicellular aquatic animals might fulfill these requirements and species of paramecia easily grown in pure culture were chosen for investigation.

A number of these organisms were exposed in a thin film of water to the vapour phase of the test gas and the lethal exposure time recorded. This was usually of the order of seconds.

All experiments were made on mustard gas and Lewisite. The relation between concentration of gas and killing time was established for concentrations ranging from 0 to 300 p.p.m.; above this amount the killing time was too short to permit accurate measurement. High concentrations of Lewisite were found to be more toxic than equal amounts of mustard. At low concentrations the reverse was true. The test was most useful between 10 and 100 p.p.m. of both gases. This procedure would appear to be most useful as a laboratory method of evaluating toxicity and determining with reasonable accuracy the concentration of gas-air mixtures within certain limits.

Only one of the smaller studies arising out of this work has so far been published since security restrictions did not apply. A new method for obtaining bacteria-free paramecia was devised. The animals were passed through five drops of sterile media placed in the centre of Petri dishes. They were transferred from drop to drop in a small loop of platinum wire and no difficulty was experienced in catching them when a light was focussed on the drop in which they were swimming.

CROP DESTRUCTION

The slow progress of the war early in 1940 recalled the devastating effects of the blockade of Germany through 1914-1918. The modern aeroplane provides a ready means of reaching into the enemy's territory and intensive food-producing areas are theoretically more vulnerable than cities and factories which would likely be afforded substantial fixed defences. These considerations suggested study of

crop destruction through chemicals as a means of intensifying blockade effects.

The Division of Chemistry suggested the use of phytohormone chemicals which are beneficial at low dosages but harmful at higher levels. Naphthylacetic acid was selected for study as it can be synthesized readily in quantity at relatively low cost, and is one of the most active of this group of chemicals. Sodium dinitro-ortho-cresylate (available under the trade name of "Sinox") and selenium dioxide were suggested by members of this Division as meriting similar study.

Preliminary greenhouse studies demonstrated toxic effects from dosages sufficiently low that aeroplane application to substantial areas was a reasonable possibility. Consequently, series of adequately replicated plots of alfalfa, cabbage, mangels, potatoes, sugar beets and wheat were established in the field. Naphthylacetic acid, selenium dioxide and Sinox dusts were prepared by means of a pebble-mill mix with dried soil as the carrier dust. The preparations were applied to plots of 56 sq. ft. at rates of 3, 9, and 27 lbs. of the active chemical per acre. Sinox was also applied as an aqueous spray at rates of 5 and 15 lbs. per acre using 100 gal. of solution to effect uniform treatment of one acre. Some plots were treated immediately after seeding and others at different stages of growth. All experiments included a sufficient number of untreated control plots.

Naphthylacetic acid reduced the yield of cabbage, mangels, potatoes and sugar beets between 30 and 75%. Sinox treatments effected very marked injury to alfalfa, mangels, potatoes and sugar beets, yield being reduced between 30 and 100%. The most injurious effects occurred after applications in the early stages of growth. This tendency was particularly marked for treatments with Sinox. Wheat was insensitive to chemical treatment though Sinox application at time of flowering caused slight reduction in yield.

Selenium treatments had little effect on yield, but resulted in wheat with as much as 5.8 p.p.m. of the element; wheat straw with 11 p.p.m.; young cabbages 50 p.p.m. and matured cabbages with 14 p.p.m. Such concentrations would render the crops a hazard to health if ingested in any quantity over a period of time.

These results were considered sufficiently promissing to warrant preliminary study of application to test areas from the air. However, German successes of 1940 made available to them the entire agricultural assets of most of Europe, and augmentation of blockade effects by chemical destruction of crops could at the best have inconsequential effects on total German food supplies. Consequently, the project was dropped as strategically inadvisable.

CAMOUFLAGE

The Division was asked by the R.C.A.F. in August 1941 to develop a method for spray treatment of grasses and vegetation to effect darkening without killing the plants. It was necessary that visibly darkened areas appear dark when photographed with either panchromatic or infra-red film. A sprayed grass field would then appear to be a ploughed field from the air, and this wrong impression could not be readily detected by photographic means. The request intimated that aqueous mixtures of iron salts and wattle (a tanning extract) had been considered in England but there were no available details as to mixtures, methods or rates of application.

Numerous test plots each of 4 sq. yds. were sprayed with various mixtures and concentrations of chemicals. Spray applications of 4 oz. of ferrous sulphate ($FeSO4.7H_2O$), 0.6 oz. tannic acid and a small amount of any one of a number of wetting agents to this area led to darkening which met all the required conditions. It was desirable to use an aqueous mixture in which the specified amount of chemical was applied at the rate of 350 gal. of solution per acre, the wetting agent being present to the extent of from 0.1 to 0.2%. More concentrated solutions were uniformly satisfactory for ordinary grass stands. Selection of a suitable spray nozzle made it possible to make one application of the mixture of chemicals.

The investigation was extended to a study of tannate sources readily available in North America. Various tanning extracts were either purchased or prepared in the laboratory. Extracts of oak bark, quebracho and hemlock were not so desirable but could be used. A combination of sumac or chestnut extracts with ferrous salts yielded darkening fully the equal of that attained with tannic acid. Approximately 133 lb. of chestnut or sumac extract could be used with the ferrous sulphate from 60 lb. of scrap iron for the treatment of one acre.

The black coloration was satisfactorily maintained for a period of three weeks in spite of heavy rains. The maintenance of colour depended obviously on rate of growth of vegetation. The experimental results indicated that periodic applications of dilute iron and tannate solutions through the growing season, at intervals of approximately two weeks would be adequate for colour maintenance. There were no adverse effects on growth of vegetation.

SHELL EGGS

Britain's loss of European sources of supply brought a demand for Canadian eggs. Eggs-in-shell have a morale, as well as a nutritional value, although they require considerable shipping space. Canada had exported a negligible quantity of shell eggs to Britain prior to the war, and this unprecedented demand had not been anticipated. During the warmer parts of the year, slow convoy transport in unventilated and unrefrigerated holds resulted in spoilage of prohibitive levels by ordinary standards. In July, 1940, the Department of Agriculture requested that information be procured on the oiling of eggs for shipment to Britain. An immediate study of preservative treatments was undertaken, but as the problem had not been anticipated, laboratory experiments had to parallel commercial shipments.

Since none of the methods yet devised for preserving eggs is ideal, the investigation was extended and 21 treatments were tested on eggs stored at 70°F. and 90% relative humidity. The best results were obtained by conditioning in carbon dioxide to lower the pH of the white, disinfecting the shell surface and then sealing the shell. Vaseline was one of the best agents for sealing the shell against carbon dioxide and moisture loss. Polyvinyl alcohol was also an effective sealing agent and when dimethylol urea was combined with it, it also inhibited growth of microorganisms. The commercial applicability of these methods is however doubtful. Packing oil-dipped eggs in moisture-vapour-resistant bags was satisfactory and capable of commercial application. The results of these experiments have been published.

A method was devised for washing the organisms off the shells in a Waring Blendor, thus allowing a study of the relation between the number of bacteria and moulds on the shell surface and subsequent spoilage. The number of organisms on eggs collected with the minimum of handling was much less than on those collected in the usual manner. This was correlated with subsequent mould development and

bacterial spoilage on storage. Disinfection of the shells of market eggs did not improve their keeping quality and was not a substitute for careful and sanitary handling. Oiling as well as handling was found to increase the amount of external mould.

The efficacy of oiling eggs and of packing them in moisture-vapour-proof bags was tested under adverse storage conditions (70°F. and 90% relative humidity). A combination of the two treatments gave the best protection against internal defects and external mould. Oiling alone was definitely beneficial but bagging alone was detrimental. Initial condensation on the eggs and packing materials produced by conditioning the packed crates at 32°, 40°, 60° and 70°F., before removing to the storage room, had no demonstrable effect on spoilage. More spoilage was noted in the center trays and the inside rows of crated eggs, probably due to humidity differentials.

As a result of the above work, three experimental lots of eggs were shipped to England in August, 1941. Eggs oiled and packed in moisture-vapour-proof bags showed much better quality on arrival but the incidence of mould and bacterial spot rot was not reduced. This did not substantiate the laboratory findings, and it was thought the difference might be due to fluctuations in temperature and humidity experienced during the trip. This possibility was checked by storing untreated eggs and eggs oiled and sealed in liner bags at alternating temperatures and humidities. This work indicated that fluctuations in temperature are not important provided the fluctuations are not around the dew point. All oiled and bagged eggs were in better physical condition than the control eggs.

At the close of 1941 none of the hastily undertaken experimental work had progressed sufficiently to offer much promise for reducing wastage in commercial shipment. Moreover the shipping situation was becoming worse. In February, 1942, the British Ministry of Food ordered that all eggs were to be shipped in the fried form; further work on shell eggs was suspended.

The problem of storing shell eggs at ordinary temperatures was reopened in 1943. Egg production during the peak season exceeded drier capacity, and cold storage space was at a premium. The question was raised whether shell eggs could be stored for the required period in solutions of lime and salt, or in water glass (sodium silicate). In an experiment to test this point, eggs were

stored in these ways, removed at intervals, broken out and dried. These treatments were apparently contrary to good practice and it is claimed that once the film of carbonate on the surface is broken the eggs do not keep. Dried egg prepared from these treated eggs, while acceptable, was not as good as that from fresh eggs. By this time, most of the surplus eggs were being stored in the frozen state and further work was discontinued.

In the summer of 1944, with the brightening of the war picture, the British Ministry again asked for shell eggs and arrangements were made with the Special Products Board to ship some 600,000 cases in 1945.

The plan called for shipment during the colder season (late fall and winter) in unrefrigerated space. Fresh eggs were to be shipped unoiled during the first four months of the year. Subsequent shell egg supplies were to be oiled, cold stored and shipped in the late fall. In November, 1944, 166 cases of eggs were oiled at St. Mary's, Ontario, and put in storage with an equal number of unoiled eggs. Twenty cases, each of oiled and unoiled eggs were shipped at approximately monthly intervals, and examined in England at the Low Temperature Research Station at Cambridge. Sample cases were also received here each month and examined at about the time the corresponding consignment was received at seaboard and on its arrival in England.

These shipments were complicated by the fact that some of the eggs had been packed small end up, and were definitely of low grade on arrival. This misfortune was really a blessing in disguise as it served to emphasize the importance of proper packing, and allowed the Department of Agriculture to issue the necessary warning to the trade before any large shipments were made. These shipments also indicated that oiled eggs were more prone to spoilage by internal mould growth than unoiled eggs. However, the oiled eggs showed less loss by evaporation. Otherwise quality measurements indicated little difference in the 'short hold' eggs. Because of the large number of eggs available, commercial shipments of oiled eggs began early in 1945, and as these arrived in good condition, the experimental shipments were stopped in March.

In the meantime, extensive tests of dipping materials were under way in the laboratory. Eight commercially available light mineral oils were tested as well as a heavy oil diluted with mineral spirits, and the light oils with additions of vaseline and magnesium stearate to improve

their sealing properties. Tests conducted with day-old eggs held for 3 mos. at 70°F. and 30% r.h. definitely proved the advantage of oiling. Oiled eggs lost about one-tenth of the moisture, and were of better quality than the unoiled controls. Oils with a Saybolt viscosity of 70-90 at 100°F., preserved quality better than lighter oils. A high pour point did not seem essential as some of the lower pour point oils gave excellent moisture retention and quality preservation even at 70°F. However, high viscosity oil diluted with light oils was not satisfactory. There was no difference in results when the oils were held at temperatures of 76°, 100° and 130°F.

In making the many measurements involved in the quality tests it was found that the yolk index could be determined quite simply by measuring the yolk in situ on the broken out egg and that this measurement gave an almost perfect correlation with the usual more tedious method.

Since the above storage experiments were made in fairly dry atmospheres which accentuated moisture losses, no difficulty was experienced with mould development. However, mould growth is an important factor and two methods have been suggested for controlling this. One is the addition of an oil-soluble mycostatic agent to the mineral oil. Pentachlorophenol was proposed a few years ago but was not received favourably by the British Health authorities. The oil solubility of a number of mycostatic agents was determined, and a few which seemed suitable are now under test. The second proposed method is a heat treatment in the shell. Several heating times and temperatures have been suggested and these are also being tested.

The British Ministry require that all eggs shipped be stamped with the word "Canada". Difficulty was experienced with the ink running after the oiling, and three of the commonest inks were submitted by the Department of Agriculture for test. Only one was found suitable.

NUTRITION SERVICES AND INVESTIGATIONS

At the outbreak of the war, nutritionists felt that recent advances in nutritional knowledge should be applied with all possible speed to the needs of the armed forces. Accordingly, the Canadian Council on Nutrition, the Associate Committee on Medical Research, and the National Research Council made offers of technical assistance. Soon afterwards, the Department of National Defence requested the National Research Council to review the existing Army

ration scale, and in doing this to seek the co-operation of nutritional organizations including that of the Department of Pensions and National Health.

At conferences held in Toronto the ration scale was carefully reviewed, and a number of general recommendations were made. The most important were: the ration should be diversified to give more variety; and the Department of National Defence should obtain the full-time services of a nutritional expert to advise them on the nutritional aspects of the ration. These recommendations were accepted and put into effect immediately.

In 1941, however, the continued desire to improve the operational utility and nutritional aspects of Army rations at a time when the supply situation was becoming increasingly difficult, led the Department of National Defence to establish a Standing Committee on Nutrition. This committee was composed of Service personnel and civilian scientists including Divisional representatives and was responsible to the Minister of National Defence.

This marked the beginning of a period of close collaboration with the Department of National Defence and the Department of Munitions and Supply which had the responsibility for supplying the food requirements of the services. A screening or sieving service was badly needed to evaluate the various products and ideas submitted by the public. It soon became necessary to establish a nutritional service laboratory in this Division to investigate numerous problems referred by the Standing Committee and to assess the value of foods offered for sale to the Department of Munitions and Supply.

Thiamin Assays on Wheat Flour

Early in 1941 we were asked to examine a proposal of the British Ministry of Food for adding thiamin to flour for export. The Ministry wanted to evolve a system of inspection and certification that Canadian flour reaching the United Kingdom would fully satisfy their new requirements.

Milling chemists met with members of the staff of the National Research Council and other interested government departments to discuss this problem. The Division undertook to investigate methods of extracting and assaying thiamin, and these have been reported.

Fluorometers were required for use in this analytical work on wheat flour and also for use on dried eggs. To bridge the gap until commercial instruments could be secured, suitable fluorometers were designed and built by members of the staff.

A simple, inexpensive, visual fluorometer was produced for measuring the fluorescence of thiochrome converted from extracted thiamin by oxidation. The resulting thiamin estimations on wheat flour compare well with those obtained by other methods, and can be read to within 0.2 microgram per gram.

A photoelectric fluorometer was designed for the determination of riboflavin, and of vitamin B_1 as thiochrome. The instrument is entirely self-contained and simple to operate. It is capable of detecting thiochrome in concentrations as low as 0.005 microgram per millilitre and sufficiently stable to permit measurement of higher concentrations. By using vacuum type photocells an electric eye can be used as a null indicator and the comparatively expensive galvanometer is eliminated.

Vitamin C Intake of Troops

At one of the meetings of the Standing Committee on Nutrition considerable discussion took place on the adequacy of the regular ration for providing the vitamin C requirements. To clarify the position, Divisional investigators offered to undertake a survey of the vitamin C intake of troops in local depots on a statistical basis.

The intake of vitamin C by troops on army rations was determined by the ascorbic-acid content of the items served and their acceptability to the individual consumer. During the winter of 1941-42 two surveys were conducted to determine the individual daily intake of vitamin C from vegetable sources included in the regular issue of Army garrison rations, by troops serving in the Base Post Office and the District Depot, M. D. 3, both in Ottawa. Estimates were deduced from chemical determinations of the vitamin C content of the vegetables, both fresh and cooked in various ways. Vitamin contents, of course, had to be related to actual vegetable consumption, arrived at through a combination of enumeration and random sampling processes specifically evolved for this investigation.

Of the troops surveyed, 15-30% refused any vegetable other than potatoes and about 1% took no vegetable.

At some meals, as high as 50% of the men did not eat the entire serving they received; the uneaten residues averaged from 15% by weight of the average original serving for tomatoes to 56% for turnips. Moreover current methods of cooking left only a small fraction of the original vitamin C concentration in any of the foods served other than in the raw state. From the foregoing facts it was estimated that about 88% of the men in one unit and 70% of those in the other had a daily vitamin C intake of less than 30 mgs. from vegetable sources. Increased rentention of vitamin C in cooking could not overcome deficiencies arising from consumption habits.

Bioassay of Vitamin C

The study of Army rations revealed that their vitamin C content was usually below the level prescribed for good health by medical investigations, and that few, if any, of the troops showed evidence of vitamin C deficiency. This means that either the levels prescribed by medical authorities are too high, or that the chemical methods of analysis do not detect all of the vitamin C present. Since chemical procedures have been adopted for estimating this vitamin, very little bioassay work has been done, and the available information is of a subjective type that is difficult to confirm.

An investigation to develop a reliable method for vitamin C assay based on the growth response of guinea pigs was undertaken at the Nutrition Laboratory, Macdonald College. This problem is fundamentally a search for a diet, which when fortified with crystalline ascorbic acid, will be nutritionally adequate for breeding females, on the belief that a diet adequate for normal reproduction and growth of the young to weaning age is also nutritionally adequate for post-weaning periods.

Initially, some 16 different diets were fed, none of which proved to be successful because of the difficulty in obtaining a diet devoid of vitamin C but otherwise nutritionally adequate for normal growth and development. Considerable work was done on successive modifications of a new diet, with encouraging results. A new bioassay procedure has been developed, and the basal diet has proved entirely satisfactory for use with this assay.

Production of Vitamin C by Sprouting Seeds

The despatch of Canadian forces to guard outposts

in such places as Greenland, Iceland and Labrador brought up the question of anti-scorbutics. The Associate Committee on Army Medical Research requested information on the suitability of germinated Canadian seeds as sources of anti-scorbutic material. A preliminary investigation was made to ascertain optimum conditions for germination. Cereal crops, varieties of peas, beans and soybeans were included in the survey. The Chinese salad bean was included too, as its use in Chinese dishes is well known and appreciated. The English Windsor Broad bean was found to produce large amounts of ascorbic acid, and could be germinated at much lower temperatures than peas or the Chinese salad bean. Riboflavin production by the Windsor Broad bean was also investigated.

Methods of producing the sprouted material on a large scale were studied at Macdonald College.

Sterility Tests on Canned Pork

At the request of the Bacon Board, a number of cans of pork leaf were examined to see if they met requirements of the British Ministry of Food. Although absolute sterility was required it was found that many of the cans contained organisms but showed no signs of swelling or of spoilage after incubation at 37°C. for 4 weeks. This is in agreement with other work on meat products. Some 130 cans were examined and producers were advised regarding acceptable practices. A few cans of meat for Mess Tin Rations were also examined for the Department of Munitions and Supply.

Assessment of Food Values

In addition to the investigations of larger proportions, a considerable volume of work of a consulting and service nature was performed for the Standing Committee on Nutrition and the Departments of National Defence and Munitions and Supply. This included examinations and analyses of a variety of food materials and beverage preparations for which claims had been made of special virtues, some merited and some fantastic. The efficacy of a patented cooker in retaining vitamin C was also examined. Forty-four reports were prepared covering such items as yellow pea flakes, dehydrated soups, chocolate bars, chocolate beverage powders, fruit juice concentrates, breakfast cereal preparations and sausage filler. Investigations of greater proportions involved the testing and examination of a variety of concentrated foods, which included such delicacies as corned beef and eggs, beef, pork and tripe, tripe and eggs,

concentrated beef and vegetables, wheat meal, tripe and potatoes. In addition to routine tasting work special panel tests were conducted on such items as baking powder, buck lamb and macaroni.

Canadian Army Mess Tin Ration

In September of 1942, field trials of compact daily rations and emergency rations were conducted by the Canadian Army and R.C.A.F. Although the Canadian Army Mess Tin Ration was very favourably received, criticisms and suggestions for improving the packaging and some of the components were referred to the Division.

The composition and preparation of each individual item was exhaustively studied, and particular attention was given to packaging. The wrappings and packages were very carefully redesigned to retard deterioration of the food and to withstand the hard usage encountered in transportation. Changes in the ration components included fortification of hard candy with ascorbic acid in place of vitamin pills, the adoption of a new cocoa beverage formula, and improvement of the butter and dried milk items by insisting on an initial product of the highest quality obtainable. The ordinary wrapping used for chewing gum resulted in flavours and odours permeating the entire package and this was rectified by enclosing the gum in heat-sealed "Reynold's Metal".

A complete set of specifications covering all components and wraps was prepared and accepted by the Standing Committee. At the request of the Department of Munitions and Supply, the Division undertook to do the necessary laboratory control work during the commercial production of the new ration.

After cold weather trials in the winters of 1943 and 1944, and in preparation for the war against Japan, two new versions of the Mess Tin Ration were required and the Laboratory assisted in the preparation of these new "Monopack" rations.

Army Ration Biscuits

On September 9, 1942, a request was made by the Standing Committee on Nutrition for analyses of a variety of biscuits that were being considered for use in the Canadian Army Mess Tin Ration. As a result, a serious attempt was made to improve the nutritional properties of biscuits for Service personnel, and at the same time to provide a stable

product that could be included in rations for use under a variety of conditions.

Of recent years improvements in the eating quality and nutritional properties of such materials have been made by increasing the fat and protein content of the formula and by adding sugar and other ingredients to enhance the flavour. The addition of these ingredients introduced factors affecting the keeping qualities of the product and raised questions that could be answered only by comprehensive storage experiments. Investigations concerned with the stability of fat and protein components of biscuits, as affected by conditions of storage, were undertaken in these Laboratories and are now nearing completion.

All of the biscuits used in these investigations were prepared in commercial plants. Two firms co-operated in preparing the material used in the first phase of the work described above, so that it is possible to assess, to some extent, the effects of current plant practice on the results obtained.

In one phase of these investigations considerable emphasis was given to the stability of various types of shortening when baked in a simple biscuit formula. (Soft wheat flour 50 lbs., shortening 5 lbs. and soda. Six ounces of soda was used by one baker and 8 oz. by the other). This work was planned to relate the chemical properties of the shortenings, their storage life and response to various accelerated tests, to the behaviour of the fatty fraction of stored biscuits. The effects of varying the amount of fat in the formula were also considered for four shortenings.

Ration biscuits prepared by two manufacturers and containing 8 to 23% of one compound animal-vegetable and three all-vegetable shortenings were stored at 43.3°C. (110°F.) for 36 weeks. Keeping quality was assessed by flavour, peroxide oxygen, and pH determinations. The type of shortening was found to have a greater effect on keeping quality than the fat concentration or plant practice. Biscuits made with stabilized hydrogenated vegetable shortening were more stable than biscuits made with an animal-vegetable shortening. After storage for 22 weeks, all biscuits were judged objectionable by the tasters.

In addition, the effect of adjusting the moisture level was appraised for biscuits made with two of the shortenings. Ground biscuits were adjusted to moisture contents of approximately 0, 3, 6, 9, 12, 15 and 18% and stored at

43.3°C. (110°F.) for 52 weeks. Keeping quality was assessed by flavour tests and by peroxide oxygen, pH and fluorescence measurements. The behaviour of the biscuits was similar. Although variations in moisture content had in general small effect on flavour scores, biscuits made with the more stable shortening had differentially higher scores at levels below 6%. The evidence from the object measurements also indicated that a moisture content of about 6% was critical. Changes in the fat component as measured by peroxide oxygen were inhibited as the moisture content was increased over the range studied. The formation of fluorescing substances from protein and carbohydrate components was enhanced up to a moisture content of 12% and decreased at the higher levels.

A study was made of a number of factors in relation to the keeping quality of biscuits with a moderately high protein content, including the effects of packaging, moisture level, and leavening on a biscuit made with skim milk. In a further study, three additional sources of protein supplement, namely wheat germ, egg yolk and soya flour, were substituted in the formula and the most stable shortening available was used. The effects of method of packaging on the storage life of these biscuits were also assessed. From considerations of initial quality and of increased storage life sodium bicarbonate was superior to ammonium bicarbonate as a leavening agent, particularly at lower levels. By the same criteria, wheat germ appeared to be a more satisfactory source of protein than soya flour, dried milk or dried egg yolk.

The storage life of biscuits was extended by maintaining a moisture content of 6% or less. Moisture-resistant packaging materials were found necessary to prevent mould growth and maintain edibility in biscuits stored at high humidities; however, biscuits so packed deteriorated at a faster rate at high temperatures. Tin plate containers appeared to be the most effective for long term storage at high humidities, although Reynolds' metal A-10 with or without an inner liner was satisfactory for storage periods of about half a year at 110°F.

While none of the individual measurements used was a completely reliable measure of biscuit quality, a fluorescence measurement assessed the effects of the various treatments in a relatively satisfactory manner.

A second series of tests was undertaken to assess the effects on the fat, if any, of including various levels

of other ingredients in the formula. Accordingly, variations in components (whole wheat flour, skim milk solids, soy flour, sugar, malt, salt), quantity of components and kind of leavening were studied. A formula in which all of the above ingredients were included at single levels was selected as well, and a series of biscuits prepared in which each ingredient was omitted singly. These studies are still under way (1945).

Ascorbic Acid Stability

The Standing Committee on Nutrition recommended that a supplementary source of vitamin C be included in the operational rations (Mess Tin Ration, Monopack, etc.) that had been developed. It was agreed that these Laboratories would examine the general suitability of possible carriers and conduct storage experiments to determine their stability under a wide variety of conditions. Items chosen for study included natural fruit juice concentrates, fortified jams, candies, chewing gum, and pharmaceutical preparations.

The tablet form of citrus concentrates was given particular attention because of requirements of minimum weight and low perishability. A comprehensive experiment including all the carriers mentioned was laid down. The data showed that 70 to 80% of the ascorbic acid remained stable for protracted periods if the carriers were protected from moist conditions and not subject to temperatures in excess of 75°F. When exposed to conditions of high relative humidity and temperature the products became objectionable from the standpoint of physical appearance before the ascorbic acid losses became excessive.

When the Standing Committee asked us to recommend a suitable carrier for ascorbic acid in the Canadian Army Mess Tin Ration, results from the foregoing investigation enabled us to recommend hard candy as the most suitable carrier. This recommendation was accepted and fortified candy was included in the ration.

Vitamin A in Chocolate Beverage Powders

The inclusion in the first Canadian Army Mess Tin Ration of a commercial preparation of cocoa, dried skim milk and sugar, that was fortified with both fat and water-soluble vitamins led to questions of their stability during holding periods prior to consumption. Greatest concern was expressed about the fate of vitamin A. In consequence a storage experiment was undertaken in collaboration with the Department of

National Health and Welfare, in which four commercial preparations were stored at 75° and 110°F. for a year. Average losses ranged from 16-27%.

A larger experiment was then undertaken in these Laboratories. This involved 12 samples to which vitamin A was added in the form of a distilled concentrate, and stored at 40°, 60°, 80°, 100°, and 120°F. These included dry mixed and processed samples made principally from whole milk powder and skim milk powder; and some to which "Viobin" had been added. In addition, fortified samples made with milk and sugar, and milk alone were included. Losses from these samples were rapid at all temperatures, but those containing cocoa retained an average of 50% of the initial amount present after 50 weeks' storage at all temperatures.

STATISTICAL SECTION

During this period the special training and experience of the statistical section were more fully utilized in the war effort. These war problems included: planning of physiological tests, assistance in computing and drafting industrial data, fitting of anti-gas respirators, statistical studies of spot welding, and the nutritional status of troops. Finally, in 1942, the Head of the statistical section was seconded to the Operational Research group of the R.C.A.F. at their request and served in England, where he was attached to No. 6 (R.C.A.F.) Group of Bomber Command.

Physiological Tests

The work of the Physiological Section of the Chemical Warfare Establishment required the application of specialized statistical theory. They requested assistance and it was possible to apply recently developed techniques to their problems. For this purpose a special treatise was prepared on "The Statistical Treatment of Physiological Test Data", indicating briefly the theoretical considerations involved, reviewing in general terms the methods applicable to various categories of observations, and giving references to original sources in which these methods were described in appropriate detail.

Reconstruction

In September of 1941, the newly formed Committee on Reconstruction appealed to us for help in the rapid computation of various statistics, and the preparation of maps and charts illustrating industrial trends under the impact of war conditions in various regions of Canada. The

Committee at that time lacked competent help to do this work themselves and consequently the Statistical Section took the project over and completed the work for them in about four weeks.

Gas Mask Fitting

The Development Action Committee on Mask Design of the Chemical Warfare Establishment asked us to obtain facial measurements and to make respirator face-piece fitting observations on personnel adequately representative of the various racial stocks comprised in the Canadian Active Army. For this purpose, visits were made to military districts from the Maritimes to the Prairies. Six facial measurements were made on each of 2,292 Canadian Active Army officers and men.

The observed disparity in the average facial dimensions was greatest in respect of length and least in respect of depth. In some 90% of all individuals variations in facial length did not exceed 2.5 cm., with a corresponding limit of 2.0 cm. for facial breadth and depth. These variations represent half the maximum range observed for each dimension. Nevertheless, statistically significant differences were demonstrable between the groups of various national origin. On the average, French Canadians had the smallest faces and central and eastern Europeans the largest, whilst Anglo-Saxons showed the greatest variation between individuals. In all groups there was little correlation between length and other facial dimensions of the same individual, with the result that all varieties of contour from long and narrow to short and broad were encountered.

A total of 10.3% of those measured required a face piece of other than normal size, i.e., either large or small. However, the racial distribution of these was uneven, the Anglo-Saxons having an incidence of nearly 13% non-normals, while the average for the other groups was in the vicinity of 8½%. The foregoing total of 10.3% was made up of 6.3% of large and 4.0% small, giving an average ratio of a little more than 1.5 large: 1.0 small. This ratio in turn, however, varied with national origin, ranging from 1.2:1.0 for Anglo-Saxons to 2.8:1.0 for central and eastern Europeans.

The results of this investigation were also employed by No. 1 Clinical Investigation Unit (R.C.A.F.) in determining the sizes of oxygen masks necessary to fit the faces of R.C.A.F. personnel.

Spot Welding

The spot welding technique had not been used in Canada for metal aircraft, and in July of 1941 the Department of National Defence requested assistance in drafting specifications. American specifications were used as a base. A large number of test results were secured from American companies and were analysed statistically with special reference to the behaviour of spot welding used for various thicknesses of metal sheets. Medium and thin sheets produced "normal" distribution curves, but the curves for thick materials were skewed. The probability of exceeding or falling short of a specified tensile strength was calculated, and on the basis of these results, appropriate standards of requirement were drawn up to be used in industrial specifications. This resulted in considerable modification of American standards before use by the R.C.A.F.

Vitamin C Intake of Troops

A statistical estimation of vitamin C intake of troops on Canadian army garrison rations was made, with the results reported in the section dealing with nutrition.

Operational Research

At the time of the London blitz many valuable suggestions had been made by civilians. The Service authorities were quick to recognize the value of these contributions and operational research units comprised of civilians with specialized technical training and other qualifications were soon attached to the various Services. These experts served in a civilian capacity as advisers to the commanding officer. The R.C.A.F. adopted this system first in its anti-submarine warfare off our own coasts and later in the European conflict.

At the request of the R.C.A.F., the Head of the Statistical Section was seconded to the first Canadian operational research unit. He put in a year at Halifax on operational problems connected with anti-submarine warfare, and at the end of 1943, proceeded overseas where he functioned as scientific adviser to the Air Officer Commanding the Canadian Bomber Group.

LOW TEMPERATURE TESTS

By this time, it had become evident that the refrigeration facilities available in the food laboratories

were one of the most useful assets in the possession of the Division. Within a few weeks of the start of the war the low temperature rooms were used for testing radio equipment, aerial cameras, aircraft instruments, textiles, guns, gas masks, and a host of Service equipment too numerous to mention. Every effort was made to adjust the Division's programme to provide these services for other groups both within and outside the National Research Laboratories. Since specific satisfactory methods for making these tests were unknown at the time, this apparently routine task frequently attained the proportions of a research problem. Members of the staff acquainted with heat transfer and related problems devoted considerable time to work of this sort. Some sample problems are detailed below.

Frost and Fogging Tests

The Director of Automotive Design, Department of Munitions and Supply, personally requested that fogging tests be undertaken on triplex blocks proposed as windows for Canadian produced tanks.

The triplex blocks submitted for test consisted of armour plating glass on the outside and a sheet of transparent plastic on the inside leaving an air space between it and the glass. Four holes were bored in the plastic sheet to permit ventilation of the space. The objects were to determine whether the holes reduced fogging and frost formation, and whether the plastic used was satisfactory.

A number of windows were built of various materials with and without holes, to be compared with the submitted samples. All were subjected to test conditions simulating those encountered in the field.

It was demonstrated that holes in the plastic favoured condensation between the layers, but hastened removal of frost after a change of conditions. A sealed space between the layers was the best solution to the problem of internal condensation. Moreover, the plastic sheet was easily damaged when the frost was removed by rubbing. It was recommended that the commercially available "Thermopane" be used instead. This consisted of two layers of armour plating glass separated by a dry-air space, hermetically sealed at all edges to a metal frame.

At a later date, requests were received for similar tests on samples of windshield glass. Since no absolute test could be readily applied, the comparative method was used

throughout. This gave a quick and reliable check since the temperature and humidity conditions were similar to those met in the field. The two samples submitted were compared with seven other windows of various construction in order to obtain more adequate data. Again it was concluded that the units with hermetically sealed, dehumidified air gaps were far superior to the others, and that thicker glass gave better results.

In addition, defrosting units for use on windshields were tested for the department, and it was reported that the sample units could be considered satisfactory only at temperatures higher than 0°F. Several suggestions were made for their improvement.

Cartridge Insulation

The Fuze Division of the Inspection Board of the United Kingdom and Canada requested aging tests to determine the value of a new type of cartridge insulation under service conditions. Some 120 "vent electric" tubes were subjected to the following conditions: 140°F., and alternating between 140°F. during the day and 0°F. during the night. Over a period of a month, tubes were removed at weekly intervals and tested electrically by the Division of Physics.

LOANS OF SPACE AND FACILITIES

Throughout the entire war period, the special facilities of the Division were frequently called upon in connection with the war work of other divisions and government departments. Literally hundreds of workers annually made use of our controlled temperature rooms, ranging from -40°F. to 140°F. at 10-degree intervals. Many special storage-test conditions were provided from a few hours to several months' duration. Space was made available for the cool storage of sensitive blueprint papers and photographic plates.

Facilities for soil-burial tests required by the Textile Laboratory of the Division of Chemistry were provided at the Forest Tree Breeding field station, and in one of the controlled temperature-humidity rooms.

Eight laboratory bays together with all their existing facilities were assigned to the use of the Physiological Section of the Chemical Warfare Establishment. The space was held during the main period of the war. Until such time as their own unit was in full operation, this group was privileged to draw supplies from our stores, and in addition,

the section was permitted to use many items of our equipment chiefly for microbiological purposes and the ball-milling of war chemicals.

The services of computors and the use of calculating machines were provided on numerous occasions to those needing them.

One laboratory unit and the use of a service room was loaned to the R.C.A.M.C. for two months to enable them to build kits and boxes for a mobile nutrition laboratory for use in the Far East and to give them an opportunity to develop their technique in the use of specialized equipment.

Space and facilities were provided for an investigator from the Directorate of Signals Division of the Navy, for testing naval electronic equipment to assess its ability to withstand tropical conditions under constant use. It was found that sensitivity was maintained for at least three months under these conditions.

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D. PERIOD OF SHIPPING SHORTAGES

Shipping shortages resulted from a number of factors arising out of the war. The loss of France and the Low Countries and the fall of Norway cut the British off from European sources of food supply; submarine warfare brought about the use of convoys, slowing marine traffic; and finally, severe losses of shipping through enemy action put a tremendous strain on the carrying capacity of available cargo ships. The British required perishable food products in large volume and it became impossible to meet these demands without the introduction of emergency measures.

EMERGENCY REFRIGERATION

The standard wartime curing practices referred to earlier were adopted on the assumption that bacon would be shipped in refrigerated space at temperatures near the freezing point. By April, 1941, shortages of refrigerated shipping space were becoming critical. The following cables serve to indicate the urgency of the problem.

London April 11, 1941.

Bacon Board,
Ottawa, Ontario.

Position insulated tonnage extremely difficult and may become far worse STOP May become necessary convey bacon in ordinary stowage therefore essential that no time be lost in considering and experimenting with methods which will insure bacon arriving here in good condition STOP Please consult with your Research and Scientific Institutions and telegraph suggestions which may seem likely give desired result.

Foodkeeper

London, April 28, 1941.

National Research Council,
Ottawa.

With view to unrefrigerated transport proposed here investigate relative storage life normal and harder cures with borax and boric acid STOP Would appreciate cabled information whether your experiments already cover these and similar points or could be extended urgently in collaboration STOP Understand trial shipments under discussion Bacon Board Ottawa and Ministry Food STOP Will gladly give technical assistance this end STOP Should appreciate your advice on all points

Director, Food Investigations.

Similar communications were received by United States shippers from the Ministry of Food officials, requesting suggestions as to how bacon might be shipped in unrefrigerated space. At a subsequent meeting, officials of the American firms suggested that the bacon might be hard frozen before stowage and then shipped either in heavily insulated space without refrigeration or, alternatively, the cargo of hard frozen bacon might be surrounded with one or several layers of cargo less susceptible to damage at high temperatures and having good insulating properties, e.g., lard. During the next year or so several cargoes were transported in this manner. The results were quite successful although the special stowage problems caused some delay and the capacity of the hold for perishable cargo was greatly reduced by the peripheral layers of lard and other products used for insulation.

Following receipt of the above cables, the Bacon Board convened several meetings to discuss the general problem. At one of these the American proposals were discussed in some detail. However, Canada lacked the freezer space for freezing the relatively enormous exports of bacon and this procedure would also have complicated the handling of the products at the port of stowage at a time when help was exceedingly scarce. Moreover, Canada's exports of semi-perishable products, such as lard, suitable for insulation were small.

Most of the suggestions put forward at these meetings centred around the use of harder cures and borax treatments, as used in the last war, and the possibility of using more effective preservatives.

Since laboratory experience had indicated that such practices would be neither effective nor desirable, it was suggested that ordinary cargo holds be converted to refrigerated space by the installation of emergency refrigerating equipment. Authority was granted to examine the possibilities with the shipping companies, supply firms, and the Ministries of Food and of War Transport. This survey revealed scepticism on the part of nearly every group, but nevertheless all of them offered full co-operation.

The proposed scheme required vessels having the necessary water and electric power supply, and the use of lower holds to minimize heat transfer. These requests were granted on the understanding that installation of the equipment would not delay the vessel; and that the holds selected must not be obstructed by air trunks or other permanent gear.

Prefabricated unit equipment helped to meet the first demand but the application of insulation in the ordinary sense was impossible. With nothing but the steel plate of the hull and the cargo battens between the sea water and cargo, the only resistance to heat flow lay in the gas film on the plate. Actual measurements of the film coefficient on vertical plates under these conditions were lacking and in consequency many approximations had to be made to obtain an estimate of the refrigerating load. The use of light prefabricated equipment demanded a cold air system and a method was devised that employed the minimum of temporary moveable duct work.

M.V. "Vancouver Island"

General plans were prepared following these surveys and shortly afterwards the Transport Controller named the M.V. "Vancouver Island" for the initial trials. This vessel was previously the German "Weser", captured by H.M.C.S. "Prince Robert" a few months earlier. An extremely short period was available for fabricating the equipment but with the co-operation of the Department of Agriculture and shipping and industrial firms, the equipment was secured and installed without delaying the vessel.

The details of equipment, method of installation and the results have already been described. Briefly, the assembled refrigerating units, consisting of compressor, condenser, fan and motors, were mounted adjacent to the hatch on the 'tween deck, immediately above the hold that was to be cooled. Cold air delivery and return ducts were arranged through a portion of the hatch, thus avoiding the need of cutting the deck. The air circulation system was designed to provide a moving cold air jacket around the entire cargo in the lower hold. Air from the refrigerating units passed down a moveable vertical "tower" duct to the bottom of the lower hold. Dunnage was laid athwart-ships on the bottom of the hold and vertically on the sides and bulkheads. When the cargo was stowed a fore-and-aft channel was provided in the first layer of cargo, from the bottom of the lower duct to the bulkheads. Thus after stowing, the cold air passed down the tower duct, then along the channel, from which it spilled out beneath the cargo, up the sides or bulkheads, finally returning to the head space above the cargo and the refrigerating equipment.

The results of this trial, made without any insulation on the sides and bulkheads were generally satisfactory.

Improvements, including the insulation of the hold with blankets of Nova Scotia eel grass, were made on the next voyage, and the condition of this cargo on arrival was highly satisfactory. Automatic defrosting controls were installed on the third trial but the ship was lost on this voyage.

M.V. "Pacific Grove"

The success of the first trial of emergency refrigeration on the "Vancouver Island", prompted the Ministries of Food and of War Transport to request that another experimental installation be made on a slower vessel sailing from a more southerly port. The "Pacific Grove" ex New York was named for this purpose. The prefabricated equipment provided for this vessel was similar to that provided for the original trial on the "Vancouver Island". Owing to transport delays, however, the results of the second trial with the "Vancouver Island" were available before this installation was made, and some improvements were then incorporated.

This installation was made in the No. 1 hold and since the value of the equipment was established it was made in a more permanent manner. The units were installed on the 'tween deck as before but away from the hatch. The deck was

cut to provide cold air delivery and return ducts and the tower duct was built in next to the forward bulkhead. The fore-and-aft channel was also constructed from wood instead of being fashioned in the cargo. Access to the units throughout the voyage was arranged by modifying a ventilator. Automatic defrosting was provided but since the units were accessible it was not used on the first voyage. On the second voyage the automatic defrosting controls were used throughout and gave satisfactory results.

The results were again satisfactory from a performance standpoint but this might have been accentuated since the trial voyage was made during the cooler winter season. Less adequate data were obtained than in the previous trials in the "Vancouver Island". Practically no information was obtained from subsequent voyages but the equipment was maintained in operation for some time.

M.V. "Pacific Pioneer"

Simultaneously, a sister ship, the M.V. "Pacific Pioneer" was provided with emergency refrigeration by extending the existing refrigerating equipment on this vessel to cool ordinary cargo space. The application of the refrigerating equipment described earlier demanded the selection of vessels having the necessary power and water supply. Selection of vessels on another basis, namely those having an excess of refrigeration for existing space while assigned to the North Atlantic service, had the advantage of minimizing the amount of new equipment required. This more permanent type of installation required the use of heavier insulation and built-in air trunks, and while it could be installed more rapidly than permanent equipment, a longer time was required than for the equipment described earlier. In consequence, some of the equipment and certain other changes were made in a British port prior to sailing.

The installation was made in lower hold No. 5 which had only about half the height and bale capacity of the holds fitted with emergency units on the M.V. "Vancouver Island" and M.V. "Pacific Grove". The refrigerating equipment consisted of two fans and brine coils installed in the same hold and supplied with brine from the existing refrigerating machinery. The method of air distribution was of a more conventional type, with individual supply ducts from each cooler at deck level on the port and starboard sides of the hatchway, and return ducts at the side of the ship with inlets near the floor of the hold.

This trial, also made during the winter season, was highly satisfactory. The British Ministries of Food and of War Transport subsequently made plans extending the refrigerating facilities on some 14 vessels to provide an additional 1,260,000 cubic feet of refrigerated space for bacon shipments and a similar amount for other refrigerated cargo. These conversions were made over the period 1942 to 1944 but as the project had entered the commercial phase, little additional assistance was required. The general condition of the bacon on arrival indicated that the equipment met emergency requirements.

S.S. "Corralles"

The extension of existing refrigerating facilities, however, did not meet all of the requirements. While these extensions were still in the planning and trial stage, advice was received that the S.S. "Corralles", a fully insulated and refrigerated ship with 14 holds, had lost her refrigerating machinery. To get this ship into service as soon as possible, it was proposed to apply the emergency refrigerating units.

The computations made from available information indicated that in this permanently insulated vessel a total of four units (1 per hatch of 3 or 4 holds) should be adequate to maintain the desired temperature, although the condition of the insulation was doubtful. The sailing of this vessel from Britain was delayed for general repairs, and during this period the power lines for the units were provided and an ammonia machine installed to cool the two forward hatches in the same manner as with other emergency equipment.

On this ship it was possible to modigy the refrigerating units to incorporate the improvements that previous experience had indicated as desirable. The fans were changed to reduce the extent to which the cool air was reheated in passing through the units, and to increase the adaptability of the units to different types of holds and vessels. Additional condenser capacity was provided, the coil design was modified to provide greater surface to minimize defrosting, and automatic defrosting features were incorporated.

The initial installation comprised two units, one for each of the two after hatches installed in a manner that made use of the existing air trunks and left the equipment accessible for inspection. The first voyage was made during the cold winter months and while the cargo was discharged in satisfactory condition it was felt that more refrigerating capacity might be required during the summer season. The

two extra units originally provided for the forward spaces were therefore installed in the after hatches on the next voyage to provide extra capacity. Although no official reports were received following the initial trials, this installation appears to have given satisfactory service throughout the emergency period.

S.S. "Fleurus"

Later in 1942, another application of emergency refrigeration was made on a Canadian vessel, the S.S. "Fleurus". Frozen cargo had to be transported from Montreal to the Air Station at Goose Bay. Only small vessels were available for this duty and none of these had adequate refrigerating capacity for carrying frozen cargo, or for supplying the electrical power for the refrigerating units. Fortunately, the voyage was comparatively short and it was already known that frozen cargo could be carried across the Atlantic without refrigeration in adequately insulated space. Unfortunately the application of heavy insulation in the holds of these vessels would not only have caused considerable delay but would also have reduced the limited space available for cargo.

It was therefore decided that a hold capable of carrying about 100 tons or more of frozen meat should be lightly insulated and provided with emergency refrigerating equipment to maintain the temperature in the region of the freezing point. In previous installations, the return air temperatures had always been above the freezing point, so that stopping the compressor, by manual or automatic means while the fan remained in operation was an effective means of defrosting the coils. In this application, the return air temperature might be below the freezing point and therefore useless for defrosting.

A new coil and defrosting procedure was devised. Electrical heaters capable of consuming the amount of power required by the compressor and fan motors were built into the coil to give high heating efficiency. When the coil became coated with frost, an automatic defrosting switch shut off both the compressor and fan motors and switched the available power to the heating elements. When defrosting was complete, the heaters were automatically cut off and the motors started.

This plan required electrical power. A Diesel-driven generator with the necessary bunkerage and switch gear was therefore installed in preference to driving the compressor and fan firectly by the Diesel engine. The method

of air distribution was essentially the same as that used on the M.V. "Vancouver Island" except that another layer of insulating blankets was provided between the air-jacket and the cargo. In practice the second layer of blankets was difficult to apply effectively and was finally replaced with a layer of lumber nailed to the inside of the horizontal and vertical dunnage.

This vessel made a number of voyages during 1942 and 1943, and the condition of the cargoes on arrival was generally satisfactory. The air temperatures maintained around the cargo were generally near or slightly above the freezing point and under these conditions little or no thawing of the frozen product occurred in transit.

Laboratory Tests and Development

It became evident at an early stage that more specific data would be required for design and development purposes. As this information could not be obtained with the equipment installed on cargo vessels, similar equipment was set up in the Laboratory to obtain the necessary information. One of the points that required additional information was the effective refrigerating capacity of the units. The capacity of the original equipment was based either on computations or manufacturers' ratings, both of which assumed a frost-free cooling coil. In practice, frost gradually accumulated on the coil during the cooling period, resulting in a gradual reduction of capacity. This was followed by an indeterminate period when the compressor had to be shut off for defrosting. The rate of frost accumulation depended on the temperature and humidity of the air and also on the coil design. Experimental equipment similar to that used on the vessels was, therefore, installed in a small room where the effect of different atmospheric temperatures and humidities could be studied and improved coil designs developed.

Information from these tests yielded data from which the actual capacity under different operating conditions could be computed. Other improvements have been referred to earlier in connection with the actual installations. These include modification of the coil design to improve capacity by altering the coil serpentining and fin spacing, developing automatic defrosting controls and finally the development of an efficient method for defrosting coils electrically. As this information became available, it was incorporated in the design for later equipment.

The First Lord of the Admiralty, addressing the Refrigerating Engineering Society in London in March, 1945, revealed for the first time the important role played by emergency refrigeration in the transport of perishable products to Britain.

DRIED EGGS

In the early phases of the war, when the Germans overran the Continent, the principal British supply of shell eggs was cut off, and Japanese occupation of the Chinese ports ended the export of dried eggs from that country: the egg ration in Britain was reduced to one egg per month. It fell chiefly to the Western Hemisphere to make good the deficiencies. The problem of finding enough shipping space, especially refrigerated shipping space, to carry the enormous quantity of shell eggs became increasingly difficult in 1941. Liquid egg is 75% water, and the oval shell is particularly wasteful of packing space. In view of these circumstances the British Ministry of Food announced that it would accept only dried eggs after March, 1942. Subsequently it was estimated that the use of dried eggs in Britain saved one million tons of shipping annually.

Canada had then only three egg-drying plants producing less than 600,000 lb. of powder per annum. Two years later, powder production had been multiplied about 35 times, to the equivalent of almost a billion eggs per year; yet even this was less than 10% of the British requirements.

Hitherto, dried egg had been used mainly for baking purposes. If dried eggs were to replace shell eggs as a table dish, high quality was essential. It was obvious that if we were to retain a fair portion of the British market, every effort should be made to improve the quality of our product.

The Poultry Products Section of the Special Products Board, faced with the task of delivering millions of pounds of dried egg to Britain, turned to the National Research Council and asked that the production of high quality dried egg be carefully investigated. This problem had been anticipated, and investigations on dried egg powder had been initiated in the Division in February, 1941. These studies were now intensified.

Assessment of Quality

The first need was for a yardstick to measure

quality in the table product, since the commonly used tasting method was not always reproducible. A reasonably precise new method of measuring quality based on fluorescence was evolved. Quality was objectively assessed by measuring the fluorescence of a potassium chloride extract of the egg powder after defatting with chloroform. Measurements on a large number of samples of widely varying quality showed that the fluorescence readings were closely correlated with quality ratings assigned by flavour panels. The method attains a satisfactory level of precision, and can be standardized objectively with quinine sulphate.

Later the method was improved to avoid prolonged filtration periods and the temperature coefficient of the measurement determined in the region of room temperature where analyses are made. Increase in temperature raised the values obtained by 0.65 photofluorometer units per Centigrade degree. Variations in the pH of the protein solvent from 4.6 to 8.9 caused no significant change in fluorescence values. Results indicated that these fluorescent materials arise from changes in the protein fraction of egg powder, and that there is more than one fluorescing substance. From indirect evidence, proteose and peptone constituents appeared to be partly responsible.

Bacterial counts, moisture determinations, insolubility and acidity tests, and other procedures were adapted for use on egg powder. A refractometric method of determining solubility was also included. During 1942, samples were taken by approved methods from every carlot of egg powder produced in Canada. Thousands of analyses were made on these samples until the more promising tests were working smoothly. Further attention was also given to quality limits as assessed by taste panels. In November of that year these, including the fluorescence test, were incorporated in the Canadian Dried Egg Specifications, which were adopted by industry and enforced by the Department of Agriculture.

Effect of Drying Conditions

The previous studies indicated that variations in the product were partially due to processing methods. To study the effect of drying conditions on egg powder quality, a laboratory model spray drier was designed. It was found that lowering both the inlet and exhaust air temperatures caused marked improvement in quality, although lowering the drying temperature had an adverse effect on the rate of production.

Analyses on the colour of Canadian egg powder showed a significant difference according to plants: powders produced by cone-type driers were generally lighter than those from box-type driers. It is believed that overheating in the box-type driers darkened the powders, especially as no significant difference in intensity could be attributed to powders produced in different regions or at different seasons of the year.

Post-drying Treatment

With the aid of the new tests, it was soon found that egg powder was much more perishable than had been thought. Exposure to temperatures of from 80° to 140°F. showed that even a few hours at 80°F. caused deterioration. It had been commercial practice to barrel hot powder just as it came from the drier, and since the powder is a good insulator, it stayed hot for days, becoming unsuitable for table use even before shipment. As a result of these studies, facilities for cooling the powder within a few minutes of drying were installed in all plants, improving the quality of the entire Canadian production.

Some commercial representatives believed that a high quality powder would deteriorate more rapidly than a powder of lower quality, and that the additional cost might not be warranted. However, a series of investigations showed that the rate of quality deterioration in egg powders, as determined by fluorescence changes, is independent of the initial quality.

Factors Affecting Storage Life

Temperature -- The thermal instability of egg powders, demonstrated in early experiments showed that a study was necessary to determine suitable conditions for storage and transport. Powders were therefore stored at temperatures from 45° to 90°F. for periods up to six months. The results led to a recommendation that the temperature during storage and transport should not be allowed to exceed 60°F. Indeed, low temperature studies revealed that egg powder stored at -40°F. for eight months definitely deteriorated, as shown by an increase in fluorescence value of about five units. Calculations on the keeping quality of first-class egg powder of 4 to 5% moisture indicated that a conservative estimate for storage life at 90°F. would be ½ mo.; at 60°F., 3 mos.; at 45°F., 6 mos.; and at 32°F., 12 mos. So far as colour is concerned, little change in either total intensity or colour quality was

noted at storage temperatures below 95°F., but the powders darkened at temperatures above 95°F.

Moisture content -- Practical experience had indicated that 5% was a suitable maximum moisture content for dried egg powder, but few scientific data were available. The effect of moisture contents of 2 to 8% on quality retention at various storage temperatures was studied, and it was found that deterioration increased markedly as moisture content increased. A moisture content as low as 1.4% was effective in improving quality, but by no means rendered the product imperishable. On the basis of these and other studies undertaken at the request of the U.S. Quartermaster General Branch, it was concluded that dried eggs should contain the lowest moisture content compatible with good drying practice, probably 2% or less.

Gas-packing -- In an effort to increase storage life, powders were stored for six months at 75°F. packed in air, nitrogen, carbon dioxide, vacuum, or in compressed tablets stored in air. Carbon dioxide ahd a definite preservative action as indicated by fluorescence and especially by potassium chloride values. In additional experiments, these observations were confirmed, carbon dioxide being particularly helpful in maintaining the solubility of the powder.

Added Substances

Since exhaustive studies had shown that egg powder was a relatively perishable product, an attempt was made to render it less perishable by the addition of various stabilizing agents. Fluorescence development in powders containing sodium chloride in combination with either citric or lactic acid was more rapid than in the control powder. The addition of 15% sucrose was effective at storage temperatures up to 100°F., while 0.2% potassium bicarbonate was effective even at 120°F. Other alkaline salts studied (sodium acetate, benzoate, citrate, salicylate, and tartrate) had no effect. A further experiment in co-operation with American research organizations showed that acidifying liquid egg prior to drying did not improve subsequent storage life at 80° and 100°F.

Cooked egg containing sugar and a number of flavouring materials was also studied. Cocoa, cocoa and peanuts, and lemon additions were preferred to added malt by a taste panel.

It is generally believed that a dried product prepared from a liquid egg and sugar mixture has better baking qualities than powder prepared without the addition of sugar. Commercial production of a quantity of this material was undertaken, yielding a product containing two parts of egg solids to one part of sugar. Some difficulties were encountered in drying this, but these are gradually being brought under control. The cake volume of the product equals that of stored shell eggs (about 280 ml.), whereas ordinary egg powder has a cake volume of only 200 ml. This product is of continuing interest in the post-war period. The Ministry of Food has already ordered 1500 tons.

Bacterial Content

An excessive bacterial content in a food product is usually an indication that it is not being handled in a sanitary manner. When dried egg production began in Canada, there was little information available on the bacterial content of powders produced under good drying conditions from good eggs. As a result, considerable tolerance was allowed and a maximum of 500,000 viable organisms per gram was suggested for Canadian dried egg powder. The viable count reflects initial contamination and handling methods but gives little indication of the types of organism present. On empirical grounds it was therefore suggested that the E. coli content as an index of faecal contamination should not be greater than 100 per gram. The majority of Canadian powder met these requirements.

The bacterial content of the dried egg was influenced by: number of organisms in the melange, drying temperature, rate of cooling, storage temperature and moisture content. Growth curves on liquid egg indicated that the melange should be kept below 45°F. to prevent the development of micro-organisms. Low drying temperatures and rapid cooling of the powder favoured survival of bacteria. On storage the bacterial mortality increased with increasing time and temperature. At 45°F. and below, the majority of organisms survived eight months' storage. It should be noted that measures taken to improve quality usually favour the survival of bacteria. Up to 8.6% moisture in the powder had little effect on bacterial survival. At moisture levels above 5%, there was an increase in mould development particularly at the higher temperatures.

British authorities examining egg powder from various countries for possible pathogens found a fair percentage of the samples contained members of the Salmonella

group, and expressed considerable concern over the fact. Work was therefore started to determine the incidence of this group in Canadian powder and the likelihood of infection under normal use. All powders produced from Nov. 1942 to Dec. 1943 were examined. A method based on the most probable number technique was devised to obtain estimates of the number of these organisms present. *Salmonella* organisms were isolated from 28 of 380 samples (7.4%). A greater percentage of the B grade powder contained *Salmonella* than the A grade. None types of *Salmonella* were found. These were typed by Dr. Edwards of the *Salmonella* Centre at Lexington, Ky.

By drying inoculated lots of melange in the experimental dryer, it was found that over 99% of the *Salmonella* were killed in the process. On storage it was found that the organisms survive longer the lower the temperature. Even at 45°F. there was a 97% reduction in 8 weeks and at 30%F. a 75% reduction in 3 months. Massive inoculations of *Salmonella* organisms into reconstituted egg were destroyed when cooked as scrambled egg, omelets, and in sponge cakes, custards and muffins. It was therefore concluded that under proper conditions of handling and cooking there was little danger. As far as can be ascertained, the few outbreaks of *Salmonella* infection attributable to dried egg have been due to its use uncooked in egg nogs or when improperly cooked or handled.

Since the organisms might nultipy in the reconstituted egg, the growth curves of several types of *Salmonella* and of other organisms were determined in liquid egg. *Streptococcus pyogenes* does not grow in egg and dies off rapidly at temperatures above 60°F. This agrees with some unpublished findings that haemolytic *Streptococci* of the pyogenic type are seldom found in egg powder. Coagulase positive types of *Staphylococcus aureus* were found in a few powders. The growth curves of the other organisms indicate that multiplication is rapid at temperatures above 60°F. Both liquid and reconstituted egg should be kept well below this temperature to prevent multiplication of *Salmonella* and other possible pathogens.

It was thought that slow defrosting of frozen melange might be a factor favouring high bacterial content. A saw type defroster was designed for rapid comminution of the frozen melange and this type of defroster has proved to be useful in the industry.

Since it is impossible to guarantee that a powder does not contain Salmonella, the feasibility of pasteurizing the melange before drying was examined. It was found that heating the liquid egg to 140°F. reduced the viable count by 85 to 95% and holding at this temperature for 30 minutes reduced the viable count by 98-99% and destroyed Salmonella and Staphylococci. In both laboratory and commercial trials, quality tests indicated no difference either initially or after storage between powder prepared from heated and unheated melange.

Although the source of the Salmonella organisms is undoubtedly faecal contamination on the eggs, until recently it has not been possible to prove this. Samples of chicken faeces have proved negative; so have the shells of some 520 dozen eggs sent to the Laboratory for drying purposes from six localities across Canada. In connection with other work, baby chicks have been found carrying Salmonella bareilly and these organisms have been isolated from the shell of hatching eggs from the same hatchery. In laboratory feeding tests it was found that adult fowl would carry Salmonella in their intestinal tract for periods up to 38 days and some of the eggs alid during this period were contaminated with these organisms.

At the request of the British authorities, powders (household grade only) have again been examined from December 1944 to date (1945). Of 230 powders checked, 66 were positive (28.7%). This is a considerably higher incidence than was evident in the previous examination. Twelve types were present, including four types different from those found in the first study. In all samples the numbers were small, less than one per gram. Of 15 powders found positive here, only three were found positive in England. However, four which were negative here were found to contain Salmonella there.

MINOR PROBLEMS

In addition to the foregoing major studies, work was done concurrently on a number of minor war problems. The majority of these requests came to us from other government departments and the Services.

Disinfectants and Deodorants

Sodium carbonate had been proposed as a treatment for trench mouth (Vincent's angina) and the Dental Corps requested that its effectiveness be compared with that of

the sodium perborate usually used. On freshly isolated cultures of fusiform bacilli of two types, it was found that sodium carbonate was more effective than perborate against one strain but that neither was effective in the concentrations used against the other strain, Because of the difficulty of translating laboratory findings to actual practice in a disease of this type, clinical trials were suggested.

Before Air Force boots are rebuilt they are cleaned and subjected to a fat liquoring process. In order to protect the shoemakers as well as those receiving the reissued boots, the R.C.A.F. asked if something could be added to the fat liquor to disinfect the leather during this process. Taking into consideration the time and temperature of the fat liquoring operation it was found that Trichophyton gypseum and T. interdigitale were killed by a concentration of 1-100,000 phenyl mercuric acetate or a 1-1000 dilution of commercial formalin or dehexylin. Patch tests on eight persons indicated no reaction from phenyl mercuric acetate in this concentration.

In the course of the above tests it was noted that unleached vegetable tanned leather inhibited the growth of the organisms of athlete's foot but that chrome leather did not. In December, 1942, the Inspection Board of the United Kingdom and Canada requested us to test chrome retanned insoles for this property. It was found that they did inhibit the growth of T. gypseum, and as might be expected, were intermediate between vegetable and chrome tanned leathers.

In addition, samples of Izal as used at the R.C.O.C. boot repair shops were tested. These were found effective against bacteria but not against the organism causing athlete's foot. The Director of Technical Research, Naval Services, requested a check on the advertising claims of "Roccal" as a disinfectant. This was done and the claims were found to be substantially correct. Recommendations were also made on the value of several deodorant blocks.

The Storage of Wheat Germ

Wheat germ is an important by-product from Canada's milling industry and would provide a valuable source of food material in the event of extreme rationing. To provide a consistent supply of this product would require its storage from one producing season to another, that is, for approximately one year. It was important to determine the deterioration that might occur during such a storage period and to

assess the loss of valuable nutritional constituents such as thiamin. The results of experimental work indicated that the material was unstable when stored at temperatures of 16° and 24°C. Reducing the temperature to -40°C. extended the storage life from 7 to 18 weeks. Reduction in moisture content from a normal value of about 12.5% to 8.0% approximately doubled the storage life at 24°C. Packaging in nitrogen also doubled the storage life. Even at -40°C. sufficient deterioration occurred in three months to reduce the shelf life of wheat germ subsequently stored at high temperatures from 7 weeks to about 2 weeks. Measurements of the thiamin content indicated that no measureable decrease occurred in 26 weeks' storage at 16°C. The stored wheat germ became inedible due to spoilage without any detectable loss of thiamin content.

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E. PERIOD OF STRATEGIC SHORTAGES

The events that followed Pearl Harbour brought strategic shortages in certain raw materials. In particular the reduced supplies of rubber, agar and tin brought a new class of problem to the Divisional investigators.

RESIN-RUBBER FROM CANADIAN GROWN PLANTS

The loss of the Malayan rubber plantations, and the fact that our stock-piles were inadequate for a long war, created a strategic rubber shortage. Considerable research had already been done in America on such plants as guayule and goldenrod, and more recently the work on dandelion in the Soviet Union caused attention to be focussed on the possibility of using native or introduced plants. Keen public interest was demonstrated by the flood of enquiries addressed to the Division on this subject. Many of these letters were accompanied by samples for analysis, recommending plants ranging from cucumbers to bananas. Early in the spring of 1942, a co-operative research programme was organized between the University of Toronto, the Dominion Department of Agriculture, and the National Research Council, to examine all phases of production and processing of rubber from native grown plants.

This Division assumed responsibility for the analysis of plants of favoured genera and the development of methods of extraction. Physical and chemical testing of rubber quality was assigned to the Rubber Laboratory of the Division of Chemistry. Fundamental work on selection, cultivation, and processing was undertaken by the Department of Botany, University of Toronto, with financial assistance from the National Research Council. The Division of Botany, Central Experimental Farm, undertook to make a survey for rubber-bearing plants and to be responsible for the agronomic aspects of the problem. It was apparent from the beginning that the Russian literature contained a large volume of information on the agronomic and technological problems of natural rubber production in the temperate zone. Very few of these papers had been translated and the offer of Professor G. Krotkov, Department of Biology, Queen's University, to act as bibliographer and translator was much appreciated by all the collaborators. Research Plans and Publications also assisted with a review of the literature.

Numerous other collaborators entered as the work developed. The Division of Physics, Radiology Section, under-

took the examination of rubber by X-ray diffraction methods; the Optics Section co-operated in quantitative determination by spectrographic methods of manganese and iron contents. The Dept. of Botany, University of Western Ontario, and numerous professional botanists in Western Quebec and Ontario furnished valuable data on the distribution of milkweed.

Milkweed

The common milkweed, Asclepias syriaca L., was the only native species with a rubber content sufficiently high to warrant further extraction studies. During the summer and fall of 1942, a preliminary investigation of this species revealed the fact that rubber is concentrated in the leaves. Drying the plants in full daylight under glass at temperatures up to 60°C. failed to reduce the rubber content. Concentrates were produced by fermentative decomposition, and a gradual increase was observed in the leaf rubber content during the growing season with a maximum of about 3.5% in late September in the Ottawa district. The occurrence of good milkweed stands near Ottawa led to the accumulation during late summer and fall of a substantial supply of leaves, stems and pods for extraction studies during the winter.

Initially, the rubber was extracted from the dry leaves by the use of solvents. It soon became evident that this procedure would not be practicable commercially for recovering useful quantities of rubber from such dilute sources. Mechanical methods of extraction were developed, since laboratory trials had shown that the gum might be useful as a blending agent for GR-S.

The gum extracted from the leaves was found to contain about 40% resin, 35% rubber, and 25% residue insoluble in either acetone or benzene. The extraction method involved boiling the leaves in 1.5% sodium hydroxide solution at atmospheric pressure for periods of 2½ to 3 hours, washing until the pH reached approximately 9.5, and pebble-milling to effect agglomeration. Dry gum yields in the neighbourhood of 8% based on the weight of dry leaves were obtained. Resin-rubber gums were also extracted by this method from the stalks and pod hulls of milkweed, and from a number of other plants.

Many plants that yield a latex type of juice do not contain rubber, although they may contain resins. It is, therefore, important to establish that the latex obtained from plant sources is actually rubber and also to determine the quality of this rubber for commercial purposes. Prior

to 1943 the polymerized hydrocarbon of milkweed had not been identified. A co-operative study between the Division of Physics and Applied Biology was made on milkweed latex collected in mid-July. The hydrocarbon, separated in pure form from acetone-coagulated latex was examined by chemical and X-ray diffraction methods. Chromic acid oxidation analyses indicated that the monomer was isoprene. X-ray evidence verified these results, and fixed the polymer as the cis-configuration (rubber) as opposed to the trans-configuration (gutta-percha or balata) of polyisoprene. The solvent extracted rubber from the leaves gave no polyisoprene diffraction diagram, and was probably an isoprene polymer of low molecular weight. The average molecular weight was later found by the Staudinger method to range from 20-30,000.

While the pebble-milling procedure was successful on a laboratory scale, difficulties were encountered in the pilot plant. These difficulties were overcome by using a preliminary froth-flotation. Successful application of froth-flotation to production of resin-rubber concentrates was achieved during the summer of 1943 by the co-operative efforts of workers at the Mines Branch of the Department of Mines and Resources and the Division of Applied Biology. This method gave some promise of placing the extraction of such materials on a continuous basis. No flotation agent or chemical treatment was necessary for the separation of resin-rubber from milkweed, although additional flotation agents were found to be necessary for some other plants. The rubber-resin components of all plants studied, viz., milkweed, dogbane, goat's beard, sow thistle and wild lettuce were successfully concentrated.

Favourable results, obtained from early tests of milkweed gum as a blending agent for GR-S, led the Synthetic Rubber Technical Advisory Committee to recommend to the Department of Munitions and Supply that 600-700 acres of milkweed be grown in 1943. This recommendation was forwarded to the Dept. of Agriculture with the request that arrangements be made for growing the full acreage of milkweed for which seed was available. It was also recommended that about five tons of milkweed gum be made available for large scale testing purposes as soon as possible, either from plantings or from wild stands. If the usefulness of the gum was confirmed, plantations covering 15,000 acres were envisaged as a possibility for 1944. Agreement was reached between the Dominion and Ontario Departments of Agriculture to plant 600 acres of milkweed in Peterborough County. Science Service of the Department of Agriculture agreed to organize through school inspectors and agricultural

representatives, the collection of up to 50 tons of milkweed leaves from wild stands. The Department of Munitions and Supply made available the necessary funds for the planting and collection programs.

Pilot Plant Phases

Surveys made by the Division of Botany, Central Experimental Farm, the President of the University of Western Ontario and others indicated that the average density of wild stands was as great in the Ottawa valley as anywhere. This and other factors suggested that Ottawa would be the most suitable site for a milkweed rubber extraction plant. A cinder block building was started early in June 1943 at the John Street Annex on the banks of the Ottawa river. This was equipped with pebble mills, vibrating screen, digesting and filtering equipment, etc.

By September, storage facilities were available and by the end of the year about 40 tons of milkweed leaves had been collected and delivered by the Department of Agriculture. Early in 1944, the Pilot Plant was in successful operation. Material was extracted with boiling water for 15 min. and subsequently with 1% sodium hydroxide solution at 10 lb. steam pressure for 1½ hrs. The cooked leaves were then filtered, washed to a pH of less than 11.5 and pebble-milled for 3½ hrs. The resulting slurry was passed through a 60-mesh screen and the undersize subjected to froth flotation. Resin-rubber was concentrated in the froth, thickened and finally agglomerated in a pebble mill.

The use of milkweed floss as a substitute for kapok in life-belts resulted in large accumulations of the milkweed hulls. It was felt that this by-product should be examined for possible useful materials. A study of methods of extracting gum from the pod hulls was made during the latter part of 1944. This investigation has shown that a gum containing 84% acetone solubles, 7% benzene solubles, and 8% residue may be extracted mechanically from the pod hulls. Digestion at 100°C. for 2 hrs. in 1.5% alkali, washing to pH 9.5, pebble milling at 5.6% solids for 4 hours followed by screening on a 60 mesh, and return of oversize to the mill for final agglomeration are the processes involved in extraction. About 25% of the total acetone and benzene solubles, or 2.5% of the weight of the air-dry pods is recovered.

Investigation of the chemical composition of pod gum has shown the gum to contain a small amount (0.1%) of an essential oil with a characteristic odour, and about 50% of a fixed oil comprising glycerides or other esters of palmitic, stearic, oleic, linoleic and linolenic acids. Resin acids are absent. About 30% of the dry gum consists of α-amyrin, with small amounts of polyisoprene (6%), sterol (o.1%), resene (o.1%) and traces of calcium tartrate and soaps. The residue comprises 55.0% lignin, 40.1% ash and cellulose. The high content of α-amyrin makes this gum a chemically unique material.

Final adaption of the pilot plant process to continuous extraction of leaf gum and solvent extraction studies are now under way (1945).

Koksaghyz

Several pounds of koksaghyz seed were received from Russia in 1942, and were distributed by the Department of Agriculture to universities and experiment stations across Canada.

By December of that year, a small shipment of roots was obtained from the University of Toronto, permitting us to make preliminary extractions. At a joint meeting held in the National Research Council on December 23, 1942, the first compounded samples of Canadian grown koksaghyz rubber were exhibited. It was generally agreed that the acreage should be expanded in 1943.

It was found that sugar beet extraction facilities were not suitable for the processing of koksaghyz roots. One factory ordinarily processed in a single day twice the weight or roots expected from the entire season's growth of koksaghyz. The roots supplied by the Department of Agriculture were therefore processed in the milkweed pilot plant.

The first pilot plant extraction of koksaghyz rubber resulted from processing half a ton of fresh roots grown at the Ontario Agricultural College, Guelph, Ontario. The resulting rubber was made into oxygen masks by the Gutta Percha and Rubber Co. of Toronto. The rubber had particularly desirable qualities for this purpose.

The entire quantity of roots from the experimental plantings of the Central Experimental Farms has now been extracted, although the data have not yet been prepared for publication. About 200 lbs. of rubber was obtained.

Preliminary studies on suitable antioxidants have been completed, and the rubber is undergoing physical and chemical testing in the Division of Chemistry.

Biology and Utilization of Domestic Rubber Plants by Members of the University of Toronto and Ontario Agricultural College.

Biological studies at the University of Toronto were related to the cultural problems of two species: Asclepias syriaca L, the native, common milkweed and Taraxacum koksaghyz Rodin, the Russian dandelion. The products studied were the seed-floss and latex of Asclepias and the rubber of the dandelion root.

Culture of Koksaghyz -- The wild, diploid type has been grown for four seasons and on organic soils, loams and clays. Growth was good on every fertile soil and overwintering successful on all but clays. Fall seeding was reliable but spring seeding hazardous. Koksaghyz transplants readily developed a fibrous root system from two to four times the mass of that of corresponding seeded plants. Successful reproduction by root cuttings was achieved only when the stock roots were grown on soil that had never previously been planted to this species. The highest yield of first-year roots was slightly over 3½ tons (fresh), corresponding to about 140 lbs. of rubber per acre. In perennial stands, seed yield was meagre in the first year, rose to 125 lbs. per acre of clean, viable seed in the second and fell off sharply in the third year. There was little mortality in the course of the first season of perennial growth but losses were substantial in the second and severe in the third, from what appear to be fungal wilts. Nematode (Heterodera marioni) and root aphids also attacked. This plant is difficult to cultivate and must be considerably improved before its yield would pay for the very high costs. Garden plot tests gave the genetically mixed tetraploid type a 25% margin of superiority over the mixed diploid in yield of rubber per acre.

Rubber of Koksaghyz roots -- The average content of unselected plantings varied with conditions, particularly with length of growing season. Individual random roots varied in content from about 2% to about 19% dry weight. The apparent increase occurring in the rubber content of winter-stored roots resulted entirely from losses of dry matter other than rubber and not from rubber synthesis. Rubber from winter-stored fresh roots and prepared by alkaline cooking, contained uniformly about 6% of resins and about 20% of rubber that is difficultly soluble in benzene. Roots were supplied for the

successful test production of rubber for aviation oxygen equipment.

Genetics of Koksaghyz -- The original unselected seed represents a mixture of biotypes. Several hundred tetraploids were produced by the treatment of random diploid seedlings with colchicine and in 1945 sufficient F_1 tetraploid seed was available for planting. The developmental tempo is slower but seems less subject to retardation under certain conditions than that of diploids. Certain characters of the parental generation of tetraploids are described in a report.

Culture of Asclepias syriaca -- Perennial plots were established from mixed, wild seed with the rows at different spacings. With rows at 36 inch centres, annual cultivation is necessary but with rows at 24 inches or less, weed control is practically automatic after the first year. Maximum yields were obtained from the 24 inch spacing pattern. The maximum yield of leaf is approached in the second and of pods in the third year. The highest yield of floss was 415 lbs. and the average 260 lbs. per acre. The stands are markedly susceptible to lodging by wind in their second year. Cultivated stands, even when open, became heavily infested with aphids whereas dense, wild stands in the same vicinity escaped. The cucumber mosaic virus gained entrance to the plantations. Though no attempt was made to control its spread, it increased but slightly.

Clones of Asclepias syriaca -- Naturally occurring pure stands of several differnet varieties, almost certainly clones, have been studied. They manifest surprising differences in the yield and character of the floss. Measured yeilds from these natural clones ran as high as 700 lbs. of floss per acre. The transfer of these clones to cultivation has begun.

Biochemistry of Asclepias latex -- This latex is of great natural stability and invites biochemical investigation. Methods for carbohydrate analysis have been devised. A little pentosan is possibly present but no starch. Little, if any, sugar is present and monosacharides, including pentose, added to latex, protected against microbial activity by 1:10,000 merthiolate, react very slowly. Invertase is present but the inversion products react slowly. Enzymic protealysis is active and peroxidase is present. There is a thermo-stable oxido-reductive system associated with which is a slow uptake of oxygen and output of CO_2. The benzene soluble fraction is relatively stable.

Floss separator -- A transportable floss and seed separator was designed and built. The quality of the product was better than anticipated. The separation was sufficiently complete to permit the use of the machine for the comparative assay of the floss from different clones. In practical application it could be used in the exploitation of wild stands.

Translation and Bibliography of Russian Literature
By Dr. G. Krotkov, Queen's University

In 1942 consultative visits were paid to Dr. P. Kolachov, Louisville, the Library of Congress, the Library of the Department of Agriculture, the Soviet Embassy in Washington and two Russian book distributing agencies in New York. The periodical situation was surveyed, a number of valuable isolated references and ten detailed bibliographies were obtained. Eighteen articles were translated and eleven others abstracted. These were mimeographed and distributed to all interested persons.

In 1943, a second tour of investigation was made. This included the libraries of Brown and Columbia Universities, the New York Public Library and the libraries of the New York Botanical Garden, the Brooklyn Botanical Garden, the Boyce Thompson Institute for Plant Research and the American Russian Institute. In addition to the literature in Russian, numerous papers originally published in English in recent Russian Journals, but accessible with difficulty, were located and copied.

Polymer Corporation

The Polymer Corporation, a government-owned company charged with the responsibility of producing Canada's rubber requirements for war purposes, was faced with the enormous problem of erecting a large plant and producing rubber in the minimum of time. To assist in this highly technical field, it had the advice of the Synthetic Rubber Technical Advisory Committee. This committee on occasion requested the assistance of Divisional investigators. One of the first problems was concerned with the possibility of producing intermediates for the production of butadiene from agricultural crops.

In July, 1942, members of the Divisional staff attended a conference in the United States dealing with plans for butanediol production on a commercial scale. Detailed plans and reports were transmitted to the Corporation. Since that time, the Corporation has been kept informed of the

results of rubber investigations under way in these Laboratories. Information from other sources brought to the attention of our investigators has also been transmitted. Nine conferences were attended. In 1944, the research activities on synthetic rubber were intensified through the formation of the Associate Committee on Synthetic Rubber Research, on which the Division is represented.

PRODUCTION AND PROPERTIES OF 2,3-BUTANEDIOL

Butadiene, made from either petroleum or alcohol, was required for the manufacture of synthetic rubber. Alcohol would have to be produced from grains rather than molasses owing to the shortage of shipping. Cereal grains were available in surplus proportions and Canadian plants were able to convert from potable to industrial alcohol production.

During the critical period, investigations were initiated along many different lines. The fermentation group proposed that, rather than ferment the grains to alcohol, the production of a 4-carbon compound (2,3-butanediol) might conserve critical supplies and simplify conversion to butadiene. While it was known that certain bacteria produced 2,3-butanediol through fermentation of carbohydrates, study of these processes had not advanced beyond the laboratory stage.

Preliminary Phases

Isolation of suitable strains of organisms was begun in March, 1942. Since American workers had started similar investigations a few months earlier in the Northern Regional Laboratory at Peoria, arrangements were made to visit them and discuss common problems. At that time the Peoria Laboratory was studying the fermentation produced by species of *Aerobacter aerogenes*. Following this visit, the work at the National Research Council was intensified, and many new strains of *Aerobacter* were isolated. It was decided to concentrate on the use of wheat rather than corn as a basic raw material for the fermentation.

As a result of these preliminary studies, it became apparent that if the industrial possibilities of the fermentation were to be properly assessed, pilot plant operations would be a necessity. Visits were paid to Seagrams Industry, Lousiville, Ky., and the alcohol plant at the Northern Regional Laboratory, Peoria, to obtain a background of knowledge for the development of a Divisional pilot plant.

In December, 1942, the Division issued a comprehensive report covering all Canadian work up to that time, but because of secrecy orders, circulation was restricted to the co-operating agencies. Since that time, the work has been greatly expanded and the pilot plant has been brought into operation. The details of the programme are outlined below.

Selection of the Organisms

Studies on the isolation of Aerobacillus polymyxa showed that strains with desirable fermentative qualities were most readily isolated from pasteurized natural sources such as soil, soil water, and fresh and decaying plant materials. Rich garden soil was one of the best sources. Both cultural characteristics and fermentative capacity of the original isolates were extremely variable. In all, 100 strains of Aerobacillus polymyxa were obtained for comparative studies. Of these approximately 80 were isolated in the Divisional laboratories and the remainder were obtained elsewhere. Two years later, several hundred different variants had been selected from these original cultures. Morphological and biochemical studies were made on a large number of these strains. It was found possible to select strains which produced readily filterable mashes and gave high yields.

The bacterium formerly known as Proteus hydrophilus, the causative organism of "red leg" disease in frogs, is a typical representative of the genus Aeromonas Kluyver and Van Niel. Quantitative studies have shown that A. hydrophila carries out a butanediol fermentation very similar to that characterizing the genus Aerobacter.

A new fermentation which has aroused much interest was discovered in the course of studies on other bacteria. Using a Ford strain of Bacillus subtilis grown on glucose solution at pH 6.0 - 6.8 under anaerobic conditions, levo-meso 2,3-butanediol and glycerol were found to be the main products. Subsequent work has shown that these products may be produced in a 1:1 ratio. Minor products under these conditions are lactic acid, ethanol and formic acid. All products were isolated and identified as pure crystalline compounds.

Although various organisms were studied, fermentation by strains of Aerobacillus polymyxa received the most attention.

Culture Conditions

Particle size of wheat used to prepare mashes had little effect on the yield, provided the kernel had been broken. Prolonged cooking was harmful, but sterilization for 1 hour at 121°C. was satisfactory. Acid production in the mash may be controlled by the addition of excess calcium carbonate at the beginning of the fermentation or by adding ammonia as required. Removal of the gluten from the whole wheat mash had little effect on subsequent fermentation, but the bran, shorts, germ and soluble nitrogenous constituents are necessary for a normal fermentation. Pure wheat starch with inorganic supplements can only be partially utilized. Under anaerobic conditions fermentation of a 15% mash is complete in 60 hours; but continuous removal of the carbon dioxide reduces this time to 48 hours. The diol-ethanol ratio for anaerobic fermentations was about 1.3:1.0. Aerobic conditions inhibited the fermentation, particularly ethanol formation, and 120 hours was required for completion of the fermentation under laboratory conditions. It is possible, however, when carbon dioxide is removed by aeration, to raise the diol-ethanol ratio to 3:1 or higher. The most satisfactory fermentation temperature was about 32.5°C.

While filtration of the wheat mash removes most of the solids, the soluble solids accumulate during evaporation to form a thick syrup from which it is difficult to recover the diol. It seemed desirable to remove most of the wheat protein (gluten). Starch prepared from patent flour and, therefore, free from any aqueous extract of bran or shorts made a poor fermentation medium. Obviously, starch suspensions prepared from even whole wheat would need to be fortified with some growth factors if a reasonably satisfactory fermentation were to be achieved. The materials tested included: wheat, bran, wheat shorts, wheat germ; corn steep liquor, malt sprouts, yeast extract, dried yeast, alfalfa meal, soya beans and "cero grass" (dried leaves). It was found that wheat bran, shorts and germ could be used inter-changeably within certain limits; wheat germ becoming inhibitory in amounts greater than 0.5%. Two to three percent of bran or shorts was necessary to give a normal rate of fermentation. Of the other nutrient supplements used, 1% of malt sprouts proved to be most efficient.

Fermentation Conditions

Factors studied included effects of the amount of inoculum added, different nutrients in ground whole

wheat and starch media, temperature at which inoculum was grown, aeration, and reduced pressure. Counts of the number of bacteria were made on all samples.

The re-use of a 36-hour fermentation sample as inoculum for subsequent fermentation was studied over a number of transfers. The results indicated that backstocking would be feasible provided contamination is avoided.

It was observed that shallow layers of wheat mash were fermented more rapidly than thicker layers by A. polymyxa. Access to the oxygen in air was not a factor since exposure to an atmosphere of nitrogen gave the same result. Mashes of different depths, on exposure to an atmosphere of carbon dioxide all fermented at the same rate. This provided indirect evidence that the escape of carbon dioxide (the main gaseous product of fermentation) was a primary factor controlling the rate of fermentation. When mashes were fermented under reduced pressure, it was shown that the reduced pressure increased rate of fermentation two- to three-fold. At the reduced pressures, depth of mash had little effect on the ratio. One of the disadvantages of fermentation under reduced pressure was the relatively low diol-ethanol ratio obtained.

The most effective method usually employed for neutralizing the organic acids produced in A. polymyxa fermentation is the addition of the mash of 0.5-1.0% calcium carbonate. Experiments in the Laboratory showed that the use of ammonia for pH control was perfectly feasible and permitted normal fermentations. The ash content of the residue was about 3-4% as compared with 18-20% in calcium carbonate controlled mashes. A series of wheat mashes fermented by A. polymyxa was controlled over a pH range from 6.0-7.0 with ammonia. It was shown that 6.0 was the most advantageous pH for the fermentation; the yield of ethanol and diol are maximum, the amount of ammonia required was at a minimum, and the production of organic acids was relatively lower than at higher pH levels. There is little difference in the cost of the required amounts of ammonia and calcium carbonate.

Since ethanol is of considerably less value than diol, it is desirable to reduce its formation as much as possible. The mechanism of ethanol formation in the fermentation involves the reduction of acetaldehyde and it seemed likely that interference with the reduction stage would inhibit the formation of ethanol and increase the yield of diol. It was found that oxygen (or air) was an

effective agent for this purpose, since it altered the diol-ethanol ratio from 2:1 to about 3.5:1.0. Fermentation under anaerobic conditions obtained by the passage of nitrogen or hydrogen through the mash reduced the fermentation time to almost one-half. However, under such conditions both diol and ethanol rates of formation were increased, and the final ratio of the two products was approximately 1.2:1.0.

Fundamental Studies

Paralleling the laboratory studies of an applied character, detailed above, more fundamental studies were undertaken on carbohydrate fermentation by A. polymyxa. This investigation was a study of the fermentation of glucose, xylose, pyruvic acid and mannitol. Carbon balances were obtained for fermentations on each of these substrates. The chief products from glucose were diol, ethanol, carbon dioxide, hydrogen and small amounts of acetic acid and acetoin. In these glucose fermentations the diol-ethanol ratio was approximately 1:1. Using xylose the products of fermentation were similar to those formed from glucose, but the ratio shifted in favour of ethanol. The chief end products are acetoin, acetic acid, carbon dioxide and hydrogen with almost no diol or ethanol. In the fermentation of mannitol a large amount of lactic acid was produced, while the production of diol was greatly reduced giving a diol-ethanol ratio of 1:7.

Representatives of the Aerobacillus, Aeromonas, and Aerobacter genera characterized by diol fermentation of carbohydrates all oxidize 2,3-butanediol under aerobic conditions. A. polymyxa and Aeromonas hydrophila oxidize diol only to acetoin. A. polymyxa, which produces pure levo-butanediol oxidizes this isomer about 12 times as rapidly as the meso- form. A. hydrophila produces mainly mseo-butanediol and cannot attack the levo- isomer at all. Aerobacter aerogenes oxidizes meso- but not levo-diol carrying the oxidation to carbon dioxide and water. The reaction proceeds in two steps: a preliminary oxidation to acetoin, followed by complete oxidation of the acetoin thus formed.

Pilot Plant Studies

To obtain data on the production and recovery of diol and to obtain supplies for chemical studies, a small scale processing unit was designed for fermenting and recovering the diol from 25 gallons of wheat mash. An account of the equipment, together with results from its operation was published.

Although the contracts for pilot plant equipment had been let in 1942, it took practically a year before deliveries were completed. The major work of installation was done between December, 1943, and March, 1944; operations commenced in April 1944, and the plant has been running continuously ever since. All phases of the process have been studied as intensively as available personnel permitted, and about half the time the plant has operated on a three-shift, 24 hour per day basis. Although a number of problems still remain to be solved, the main outlines of the process have been worked out, and the fermentative production of 2,3-butandiol appears to be commercially feasible.

The process is conveniently divided into fermentation and recovery phases. The former includes grinding, slurrying, liquefying, cooking and fermentation. The latter covers various processes for separating and purifying the products and by-products.

Fermentation process -- The chief operations are as follows: Wheat, malt and calcium carbonate are delivered to bins on the upper level of the plant. From here the grain is gravity fed to the grinder and thence to the hopper, which is suspended from scales. Carbonate is added to the hopper, and the whole charge, after weighing, is dropped to the cooker, slurried with water and heated with direct steam to the liquefying temperature, 70°C. A small amount of malt, previously slurried in water, is now added. After 15 to 20 mins. at 70°C., the mash is cooked under pressure for a definite time. The cooked mash is blown either through the mash cooler or directly to the fermenting vessels, and is adjusted to the fermenting temperature of 32°C.

Prior to mashing, the whole system is sterilized with steam; as the mash cools, the steam is replaced by sterile air so that a slight positive displacement is maintained at all times. The mash is inoculated by sterile technique with an A. polymyxa culture previously prepared in the laboratory. Each fermenter takes 400-500 gal. of mash; the mash can be aerated and agitated if desired and the temperature is automatically controlled by circulating water.

Recovery process -- After the fermentation period (72-120 hr.) if completed the mash is dropped to a holding tank. The first step is the removal of the ethanol in a conventional beer still. The mash is preheated and pumped to the column through a flow controller; the column can be fed on any one of several plates. The slops leave the bottom of the still by way of a float control tank and are sent to another

holding tank. The distillate consisting of 50-75% by volume ethanol in water, is stored in the high wine tank. These high wines may be rectified to 95% ethanol in the beer kettle and rectifying column.

The hot slops are allowed to settle 12 to 36 hr. and then approximately half the volume can be decanted as clear beer. The remaining material is agitated and filtered on a rotary precoat vacuum filter. This unit is first given a precoat of diatomaceous earth by filtering it from a water slurry, then the mash is pumped in. One precoat of 1¼ in. thickness will usually handle 400-500 gal. of thickened slops. The wet solids are discarded although they can be dried if desired. The filtrate is sent to the filtrate receiver, and is then mixed with the previously decanted beer.

The next step is the recovery of diol from the large amount of water in the beer. This is complicated by the pressence of soluble solids and it is at present difficult to recover all of the diol in one operation. The beer kettle functions as a single effect evaporator except that the residue or syrup is allowed to accumulate and thicken until the end of a run. Beer is fed continuously to the kettle and the vapors are fed directly to the rectifying column, about half way between top and bottom. The distillate from the top of the column contains water. Crude diol (50-70% in water) is drained from the calandria at the foot of the column. This unit is provided with numerous instruments and controls, including rotameters for measuring the reflux and takeoff rates. The operation can be carried out either under vacuum or at atmospheric pressure. The crude diol is purified and brought up to 100% strength by vacuum distillation in a small unit.

The remaining step, probably the most critical of the whole process, is the extraction of the diol which remains in the evaporator syrup. Two methods are available. In the first, the syrup is blown hot to a precipitator in which it is mixed with 3-4 volumes of 95% ethanol. The precipitated solids are separated by settling and the ethanol phase, containing extracted water and diol, is recycled with the next batch of mash through the beer still. The precipitated solids are discarded. The second method is to strip the diol from the syrup continuously with high pressure steam, and this has proved much more successful. The diol-water condensate from the top of a packed column is recycled to the next batch of beer. The stripped syrup can be dried on a conventional type drum dryer.

Fermentation data -- In the fermentation part of the process, the main effort has been directed towards developing equipment and operating techniques to give sterile conditions, both in the equipment itself before mashing and in the cooked mashes before and after inoculation. A great deal of trouble was experienced because the available equipment was not always suitable. Many changes were made as the work progressed and there is still room for improvement. In a series of 53 fermentations made under the best conditions, 12 (Or 22.6%) were badly contaminated. In the other 41 fermentations, considered satisfactory from a contamination point of view, the average yields at 96 hr. were 9.8 lb. diol and 6.5 lb. ethanol, or a total of 16.3 lb. of desirable products per bushel of wheat, which was 95.6% of the theoretical value. Yields from individual runs varied considerably, and in addition, since the rate of fermentation tapers off to zero at the end, the time of completion is somewhat arbitrary.

Mash concentrations have not exceeded 15% and cooking was done at 115°C. for 1½ hr. It was found that batch cooking at higher temperatures was detrimental to the fermentation. It was found possible to inoculate 500 gal. of mash with as little as 2 litres of inoculum instead of the original 20-30 gal., without decreasing the average rate of fermentation or the final yields.

Recovery data -- Ninety-eight percent of the ethanol has been recovered, containing about 0.1% diol by weight which represents only 0.2% of the total diol present. The heat was supplied through a coil rather than by sparging in steam directly, thus avoiding dilution of the slops and resulting in a saving of 10-20% in the subsequent evaporation of the beer.

The volume of beer decanted from the settled slops has averaged about 60%, but may be considerably less if the fermentation is incomplete or contaminated. Filtration of the remaining material at 23 in. vacuum and a drum speed of 95 sec. per rev. gave 3.2 gal./hr. of filtrate per sq. ft. of filtering area. Unless the precoat was put on at low vacuum the rate of filtration was greatly reduced. The filter cake averaged 70-75% moisture, and on a dry basis contained about 36% of the precoating material and 25% protein.

Excessive foaming of the filtrate necessitated cleaning of the vacuum pump after almost every run. The problem was solved by bleeding into the filtrate line a

small amount of turkey-red oil. This also serves to reduce foaming in the subsequent evaporation.

Evaporation of cold beer has been accomplished satisfactorily with a steam consumption of about 1.3 lb. steam per lb. of beer. Some trouble has been experienced with fouling of the heating surface and the overall coefficient of heat transfer dropped from about 500 to 100 B.T.U./hr./sq. ft./°F. during 48 hr. evaporation. The syrup was usually removed from the kettle at a concentration of 30-40% solids and 15-20% diol. About 95-97% of the diol entering the column has been recovered as a crude product of 50-70% concentration. Above this concentration, the boiling point of the mixture increases very rapidly and thus requires much higher pressure steam in the calandria.

This crude product and the water distillate both contain some acid, therefore, all piping on this unit should be a corrosion resistant type. Some nitrogenous compounds are present in the crude diol, and these produce ammonia at the purification stage when the diol is separated from the remaining water. Repeated distillation under vacuum has been used to purify the diol. The chief problem has been in separating the acid from the diol; this separation cannot be made easily by simple fractionation since some esterification takes place. Neutralizing the acid with alkali permits the separation of diol of 99.9% purity or better. The use of alkali has several disadvantages and other methods of removing the acid are being tried.

Consideration was given to interpreting the data in terms of probable designs for a large scale plant. Tentative flow sheets for such a plant have been drawn up and preliminary estimates of the ultilities required and initial and operating costs made. A brief description of the plant has been published.

Chemical Studies

It was shown that the 2,3-butanediol produced by A. polymyxa was a pure levorotatory isomer $[\alpha]_D^{26} = -13.34°$ Fractional distillation through a Stedman column and fractional crystallization of the mono-acid d-camphorate and mono-acid phthalate permitted the detection of 1 to 2% of the meso- or dextro-isomers in the levo-isomer.

The dehydrogenation of 2,3-butanediol vapor by copper and nickel catalysts was studied intensively. It was found that acetoin, diacetyl, and hydrogen were produced in

almost quantitative yields over freshly reduced copper. The kinetics of this reaction were studied and a comparison of 2,3-butanediol with other alcohols and glycols was made. An explanation was provided for the greater ease of dehydrogenation of the secondary alcohol group as compared with the primary. A simple means of expressing the activity of this type of catalyst was developed. This reaction provides a simple means of preparing acetoin from 2,3-butanediol.

Dehydration of 2,3-butanediol can be readily accomplished by heating with sulphuric acid in the liquid phase. The main products are methyl ethyl ketone, water and the cyclic methyl ethyl ketal of 2,3-butanediol. This reaction could be carried out as a continuous process by allowing the products to distill out of the reaction mixture, and feeding in 2,3-butanediol to keep the volume constant. Under reduced pressure, 2,3-butanediol can be converted to the cyclic methyl ethyl ketal in yields approaching 95% of the theoretical.

The methyl ethyl ketal of 2,3-butanediol is a mobile colourless liquid with a boiling point of 134°C/760 mms., immiscible with water, but miscible with petroleum. It is readily hydrolyzed by dilute hydrochloric acid to an equi-molecular mixture of 2,3-butanediol and methyl ethyl ketone. Since it can be prepared from 2,3-butanediol more easily than any other compound its chemical properties are being studied further, particularly its pyrolysis in the presence of dehydrating catalysts. It can be decomposed to methyl ethyl ketone with practically no side reactions. With an aluminium oxide catalyst the reaction was more violent, and an unidentified mixture of higher boiling compounds is produced along with the methyl ethyl ketone, as well as small amounts of butadiene, butylenes and gases. In the absence of a catalyst, very little change occured until a temperature of 600°C. was reached, and then a relatively large amount of gas was produced as well as methyl ethyl ketone and butylenes.

Uses

Aqueous solutions containing 50-60% of levo 2,3-butanediol are suitable for use as winter radiator fluids, with no objectionable characteristics. This conclusion resulted from study of (a) comparison of levo, meso-levo and meso-dextro mixtures of 2,3-butanediol as freezing point depressants, (b) comparison of levo 2,3-butanediol samples obtained from different strains and recovered by different

distillation methods, (c) anti-freeze properties of ternary systems containing water, levo 2,3-butanediol and one of the following: ethylene glycol, methyl alcohol, ethyl alcohol and tetrahydrofurfuryl alcohol, (d) coefficient of expansion and boiling tests on selected liquid systems, (e) density, refractive index and optical rotatory power of levo 2,3-butanediol dissolved in water, (f) driving tests. In addition, viscosity measurements were made by the Division of Mechanical Engineering, and tests on corrosiveness and rubber softening by the Division of Chemistry. A suitable test for diol concentration after use in the radiator is based on a measurement of levorotatory power in a simple polarimeter in which polaroid discs replace Nicol prisms, an ordinary Mazda lamp serving as light source.

During the winter of 1944-45, road tests on the performance of 2,3-butanediol as an antifreeze fluid and engine coolant were made in a number of trucks and cars belonging to these Laboratories. Four vehicles were filled with butanediol mixtures and two with standard ethylene glycol mixtures for comparison. Butanediol was tested at two strengths, 50% and 60% in water. Small amounts of sodium nitrite were added to inhibit corrosion, and the pH of the mixtures was adjusted to 7.0-7.5 with tri-ethanolamine. These tests extended over a period of three months. The vehicles received more than average use and temperatures ranged as low as -25°F.

The butanediol performance compared favorably with that of the ethylene glycol in all respects save one. The pH of the diol mixtures dropped to between 5 and 6, and this caused some corrosion. It is believed likely that the original diol contained a small amount of diacetate ester which hydrolyzed in the water mixtures and set free acetic acid. The corrosion laboratory of the Division of Chemistry has been co-operating in attempts to find satisfactory corrosion inhibitors for such mixtures.

Related Studies.

As the work on fermentations progressed, the need for storing large numbers of pure cultures increased. Methods of culture preservation in current use at the Northern Regional Laboratory of U.S.D.A. and in the Dominion Department of National Health were surveyed and the best features of both were used in developing a system for Divisional use. An apparatus was built in which large numbers of pure cultures could be dried under vacuum at low temperatures. The ampoules can then be sealed off and

stored at ordinary temperatures. Some 3,000 cultures are now held in our collection. This storage method is still under study, with particular reference to the viability of stored organisms.

Ethylene glycol is used in aircraft-cooling systems chiefly in anhydrous form. While absence of water leads to improved engine performance, the coolant lacks anti-freeze properties. High temperature coolants with anti-freeze properties have been studied by conducting freezing point and viscosity measurements on anhydrous blends of ethylene, propylene, tetraethylene and butylene glycols, 2 ethyl hexanol, furfuryl and tetrahydrofurfuryl alcohols. One:one anhydrous mixtures of ethylene glycol with propylene, methylene or diethylene glycol were the more promising of the many blends tested. Butylene glycol blends were less suitable because of higher freezing point and viscosity. The most important result of this work was the demonstration that pure tetrahydrofurfuryl alcohol has a low visocisty even at -100PF. and a liquid range of 450°F. This liquid is derived solely from non-digestible agricultural crop residues.

Numerous enquiries in the field of fermentation and the industrial utilization of wheat have been answered by members of the Division. The interest in glycol production has been particularly keen. In addition, there has been wide interest in other war chemicals supplied by fermentation, e.g., the Secretary of the Shipping Priorities Committee requested information on the production of glycerol, and other enquiries have been answered on the production of lactic and citric acids.

PRODUCTION OF ALCOHOL FROM WHEAT

Initially, the petroleum industry was unable to meet the immediate demands for butadiene for synthetic rubber production. As an alternative, the distillers were abel to provide sufficient quantities of alcohol for this purpose with their existing equipment. However, shortages of molasses and corn in Canada and United States necessitated the use of wheat as a raw material for industrial alcohol production. So little was known of the behaviour of wheat fermentations and so many difficulties were encountered in early work, that the U.S. War Production Board set up a Wheat Alcohol Committee to study the problem and disseminate information to commercial plants.

The National Research Council was invited to represent Canadian interests on the Committee.

Since most of the studies undertaken by the Committee were on a pilot plant scale, the Research Council was not able to take part in the experimental investigations. However, all research reports of the committee were available to the Research Council's representatives. The information contained in these reports was made available to Canadian distillers and was valuable in assisting them to solve their operational problems. In addition to starch and alcohol analyses, the main assistance given to the Canadian alcohol industry was this consulting service, supplemented with information gained from extensive laboratory experience in many fermentations.

FRACTIONATION OF WHEAT

The accumulation of great surpluses of wheat in pre-war years accentuated the need for research directed towards the industrial use of this product. A combination of limited transportation facilities and continued good crops maintained the surplus during the early war years.

Canada's domestic supplies of starch and sugar became exceedingly limited during this period. Most of the starch used on the North American continent had been made from corn, and the equipment and methods employed were not suitable for extracting starch from other cereals. Corn available to Canada was reduced first by the shipping situation and later by a supply shortage since alcohol production for rubber demanded large amounts of corn. These limitations occurred at a time when greatly increased quantities of starch were required by war industry, and for the production of syrups and glucose to augment the short supply of sugar.

Prior to 1940, Canadian starch requirements were met by domestic manufacture from imported corn and potatoes. In addition certain other starches such as sago and tapioca were imported directly. The substitution of wheat starch for imported starches was hampered by lack of an efficient, economical method of preparing it from either whole wheat or flour. Work on this subject done prior to and during the early stages of the war was now brought to completion.

Mechanical Separation of Starch and Gluten

The separation procedure consists of mechanical kneading of a stiff flour dough in water, continuously withdrawing the starch suspension, settling out the starch and returning the supernatant liquid to the washing vessel. The main feature of the equipment was an oscillating hemi-cylindrical vessel which, in combination with a free-swinging roller provided the kneading and washing action on the dough. The amount of water required to effect a starch-gluten separation was about 8-10 times the weight of the dough. Total starch recovery was 95-97% while the gluten recovery averaged about 95%. Since the starch had a nitrogen content between 0.1 and 0.2% it was necessary to subject it to minor refining such as washing and re-tabling.

The gluten obtained from this process contained about 10% starch and its reduction to a starch-free basis was the subject to further work. However, dough-washing for 90 minutes reduced the starch content of the resulting gluten to 0.78%. Since appreciable amounts of starch are undesirable if gluten is to be used for fibres, plastics or glutamate manufacture, this method of making highly purified gluten contributed toward providing a suitable raw material.

Continuous Separation Process

While the process described above provided efficient separation, it was not directly amenable to large scale commercial operations for which a continuous separation process was desired. Patent flour was mixed with 80% of its weight of water to form a soft dough; if whole wheat flour was used, 110% of its weight of water was necessary. By agitating the dough in about 10 times its weight of water the starch is almost completely removed and gluten remains in the form of small curds. The two fractions are separated by passage over a vibrating screen. The gluten passes over the screen while the starch suspension passes through. Gluten recovery is almost quantitative but the product contains 15-20% starch. Shredding of the crude gluten followed by rewashing and screening reduces its starch content to about 10%. The starch which is recovered from the operation in 90-95% yield contains about 0.4-0.5% protein and is suitable for fermentations or conversion to syrup and sugars. The process has been found to be applicable to low grade wheats and flours which are ordinarily available at low market prices. Simplicity and continuity are the main features of this process which made it suitable for large-scale operation.

Starch Separation Pilot Plant

A pilot plant capable of handling 200-lb. of flour has been put in operation with even simpler equipment than was used in the laboratory and good results have been obtained. When the resulting gluten is dried in air or under reduced pressure at low temperature, it is suitable for fortifying baking flours deficient in gluten content and quality.

Starch Analysis

Polarimetric methods for the determination of starch have attracted considerable attention because of their simplicity. Despite sixty years of active publication on this type of starch analysis, however, no mention is made of it in official handbooks. With no acceptable reference method in existence, calibration of the polarimetric procedures devised here in 1941 had to be based on intensive studies of the polarimetric method itself. Procedures have been developed in these Laboratories for the rapid determination of starch in all of the common cereal grains and flours, aqueous starch and flour slurries, gluten, commercial starch, liquefied mashes and cooked products.

The determination of residual starch in wheat gluten was the first problem undertaken. The method which was devised is the only rapid method for starch in gluten as yet described and it has already been applied to several thousand samples in the course of the starch-gluten separation studies. Its development entailed improvement and better definition of the conditions of the analysis, introduction of stannic chloride as protein precipitant, investigations of the particle size and extraction time requirement and calibration of the method against glutens of known starch content.

Procedures were developed for the direct determination of starch in wheat, corn, rice, rye, barley, sorghum and buckwheat products. Reliability of the method when applied to wheat samples of widely different protein contents, the effects of non-starch wheat solids on the polarimetric measurement, and the particle size requirements were among the problems investigated. Existing information on the starch content of Canadian wheat is based entirely on the calcium chloride polarimetric method. To learn the cause of inter-laboratory differences, an intensive study of all factors which could conceivably affect the polarimetric measurement was undertaken. It is believed that the causes of these fluctuations have been established.

Russian and American investigators have claimed that the specific rotatory power of the same type of starch varies because the conditions of growth influence the configuration of the starch. A study was made which entailed preparation of sixty prime quality starch samples representing twenty different plant genera of species, their analysis for non-strachy constituents and determination of their specific rotatory power under standardized conditions. When adequate methods for preparing and analyzing pure starches are employed, their specific rotations are remarkably constant.

Wheat Syrup

The sugar shortage and restricted supplies of corn led Canadian and American firms to turn to wheat as a source of syrup and glucose. U.S. and Canadian factory products have been analysed for solids, ash, nitrogen, reducing sugar and polarization value. None of the factory products examined were equivalent in quality to commercial corn syrups. Wheat syrup made from soft flour was decidedly inferior in taste and appearance to syrups made from essentially pure starch. Failure to remove the protein and fats from wheat prior to its conversion to syrup was the source of most of the manufacturing difficulties.

Natural Sources of Fructose

Fructose has many potential uses but industrial developments have been retarded in the U.S. and no work of any kind has been done on the subject in Canada. It has been claimed that the taste quality of starch syrups is vastly improved by the addition of fructose. Existing information on natural sources of fructose and technology of its manufacture have been reviewed and summarized in a report.

Hemicellulose Studies

The pentosan of wheat endosperm was shown to have two important effects on the separation of wheat flour into starch and gluten: its presence in wash water prevented the re-use of the water on fresh lots of flour since then the gluten will not from a coherent mass which can be worked; and the proncunced affinity of the endosperm pentosan for water led to the formation of pentosan jelly-starch aggregates, these constituting the so-called "Squeegee" starch.

The pentosan of wheat endosperm has been isolated in essentially pure form from different kinds of flour. The hemicellulose of wheat bran has also been isolated in

fairly pure form. Both of these preparations were found to be soluble in hot calcium chloride and both are weakly levorotatory. After acid hydrolysis the hydrolysate is dextrorotatory -- just the opposite of what happens when sucrose is hydrolyzed.

In flour milling operations, furfural-yielding constituents enter all mill streams but the polyuronide fraction was restricted to the offal or feed fraction. The customary apparatus for the determination of uronic acids was improved by excluding furfural from the baryta absorption tower and by designing a new absorption tower to replace the awkward Truog apparatus employed previously.

Consulting Service

Considerable assistance has been given to starch plants in Canada, particularly those converting from potatoes to wheat as a raw material. Excluding starch analysis, little laboratory work was necessary as solutions to most of the problems were found in the literature. Routine analyses of flours, starches, glutens, mashes, emergency ration biscuits, jams, fruit juice concentrates, beverage drinks and tree saps for content of starch and sugar were performed as a service to other laboratories. Fermented mashes were analysed for residual carbohydrates at the request of the Department of Agriculture. The Division also participated in collaborative studies of starch methods (A.O.A.C.). Numerous enquiries from starch and fermentation industries were answered.

IRISH MOSS

The Japanese controlled the world's supply of agar agar, and new sources of supply had to be found. Work was immediately initiated in the Division, and a preliminary survey of available agar showed that Canada had sufficient to supply the needs of bacteriological laboratories for a considerable time, provided that none was used as a jelling agent for the canning industry. Attention was immediately directed toward the gelose extractable from Irish Moss (Chondrus crispus). Extracts of this sea-weed were in current use as a stabilizer for chocolate milk drinks, and were also used in the manufacture of ice-cream and pharmaceutical preparations. A large potential supply was available from the Maritime provinces. Later requests for information were received from the Fisheries Research Board and the Departments of Agriculture of N.S. and P.E.I., and these investigations were intensified.

Aqueous extracts of Irish Moss, while extremely viscous at 2 to 3% concentration, seldom have the properties of a true jelly. As a stabilizing agent they are not required in concentrations in excess of a fraction of a percent, and at such dilutions the colour or flavour of the extract is not detectable. The problem was, therefore, one of obtaining an extract with the desired jelling properties and sufficiently free from colour and flavour to permit its use in higher concentrations. Earlier findings indicating that the addition of potassium chloride resulted in a satisfactory jelly, were confirmed. Treatment with carbon black reduced the odour and flavour to a level that permitted its use in 2% concentrations.

Extraction

Preliminary investigations on methods of extraction of gelose from Irish Moss showed that 30 to 60% of the total moss solids were extracted in half an hour with hot water. The amount of gelose extractable depended, to a large extent, on the type of moss. Leached, bleached moss gave the clearest extracts. By using a counter-current extractor, it was possible to obtain an extract containing as much as 1.8% of extracted solids. The disadvantage of the counter-current method was that three extractions were necessary to remove about 40% of the total moss solids. It was later found that fine leaf particles could be removed from the solution with the Sharples supercentrifuge, and in this way the yield obtained from one extraction was as high as that obtained by three extractions without centrifuging. A study of the effect of the pH of the extraction medium on the quality and quantity of gelose extractable from Irish Moss showed that the optimum range for extraction is between pH values of 6 and 7.

Purification

The extract obtained by the above methods had an undesirable colour, odour and taste, and contained some suspended solid material. Purification was accomplished by treatment with activated charcoal and filtration through diatomaceous earth. It was originally thought that the viscosity of the solution was the limiting factor in filtration, but later showed that the presence of small leaf particles in the extract was the real cause of the filtration difficulties. The removal of most of these particles by centrifuging allows rapid filtration of the resulting solution.

Drying

Various methods of drying the prepared extract were investigated, viz., spray drying, drum drying, tunnel drying, and by exposing a concentrated extract to air at room temperature. The products obtained by these methods were capable of forming jellies, but only in concentrations considerably higher than are use in agar jellies. Consequently, attempts were made to increase the gelling power of the extracts. Investigation of the effect of various salts on the jelly strength confirmed the results of previous workers who had shown that the addition of potassium salts greatly enhanced the gelling power of this material. Addition of one part of potassium chloride to three parts of gelose produced a product which in 2% concentration gave a jelly comparable with agar.(2).

Attention was then turned to the possibility of concentrating the jelly by freezing out the water. The Japanese method of concentrating agar involved slicing the jelly in pans and then freezing. Practically pure ice formed in the cuts, concentrating the agar in between. On thawing, the water from the ice drained away, leaving wet agar strips to be dried at room temperature. If such a process were to be applied to Irish Moss, part of the added potassium chloride would be lost with the melting ice. If the jelly were frozen in a flat tray the ice could be separated mechanically from the contracted sheet. Approximately 90% of the water was removed in this way. The contracted sheet was dried to a residual moisture content of 8 to 10% at room temperature in about 2 hours, if the surrounding air was kept in motion by a fan. It was found that drum drying yielded a product which has a much lower viscosity when redissolved than the product obtained by freezing. However, the method of drying appeared to have little effect on the suspending power of the material or on the strength of the resulting jelly.

Use in Foods

The product prepared by the methods described was tested as the gelling agent in canned chicken. A consumers' taste panel showed that of 45 tasters, 71% preferred Irish Moss jelly to agar, 18% preferred the agar, and 11% could find no difference. Samples prepared in this Laboratory were sent to two commercial canneries and both reported that the product was as good as, or better than agar for use in canning chicken.

The material was also tested as a substitute for pectin in grape jelly and for gelatin in three standard desserts. It was not as desirable as either of the commonly used gelling agents but a taste panel considered the products acceptable.

Quality Tests

As yet, attempts to devise satisfactory quality tests for gelose have been unsuccessful. The quality tests used in the laboratory are: ability to suspend chocolate in milk, and viscosity as determined by the McMichael viscosimeter. The viscosity-concentration relation has been investigated. It was found that the viscosity values obtained with the McMichael viscosimeter are related logarithmically to the concentration of the solution.

Storage Studies

The effect of storage temperature and humidity on the stabilizing power and viscosity of dried extracts is being studied. Viscosity has been found to fall off rapidly for products stored at temperatures above 90°F., the loss being more rapid under conditions of high humidity. Storage in nitrogen, oxygen, or vacuum, and lowering of the residual moisture content of the material had little effect on these changes. Samples prepared in this Laboratory and stored for seven months at temperatures up to 90°F. and relative humidities up to 75% showed no change in their ability to suspend chocolate in milk.

Gracilaria

A request was received from the Department of Fisheries for information on the characteristics of Gracilaria mucilage as a source of gelling material. A short report was prepared comparing the principal sources and the chemical composition of Gracilaria, Chondrus and Gelidium.

SUBSTITUTE CONTAINERS

In 1941-42, as a result of the fortunes of war, our supply of tin was seriously curtailed, shipping space was at a premium, food commitments to our Allies were greatly enlarged, and an overseas army had to be provisioned. Obviously, as many foodstuffs as possible had to be concentrated and rendered less perishable; in most cases this was accomplished by dehydration. The problem of packaging unprecedented quantities of dehydrated foods, therefore, became one of the major problems

facing science and industry. Protection against water-vapour liquid water, oxygen, greases, moulds, insects, rough handling, etc., had to be considered. Although the main requirement for the preservation of most dried foods is prevention of moisture uptake, in some products oxygen must also be excluded.

The use of strategic materials, was, of course, automatically eliminated; shortages of caps and closures, lack of suitable packaging machinery, transport difficulties, availability and cost for the most part ruled out such items as non-strategic metals and glass. The choice of packaging materials was, therefore, narrowed down to wood products, their derivatives and plastics.

Resistance to water-vapour was claimed for many commercial products of this nature but each manufacturer based his claims on his own standards of comparison. An independent authoritative body was needed to correlate data, develop standard tests for assessing moisture-vapour resistance and advise on the suitability of packaging materials. Numerous requests for the National Research Council to undertake such work came from government departments and industrial concerns, with the result that the investigation of packaging problems was undertaken by this Division.

Tests on Materials

A wide range of available materials and package types was tested. The usual vapometer method for testing the water-vapour resistance of sheet material was employed. However, if films were to be made into packages, they had to be folded. It was found that after folding, some coatings lost their water-vapour-resistant qualities. Finally, a barrier excellent in sheet form may make a mediocre package if ineffectively sealed and closed. Indeed, even under the best conditions, the final package is generally two to ten times as permeable to water-vapour as the original stock tested in flat form.

The three main types of package considered suitable for dried foods are as follows: wax-dipped cartons, which provide a moisture barrier on the outside; cartons over-wrapped with moisture resistant materials; and the bag-in-carton type, which places the barrier on the inside. A number of these were constructed, particular attention being given to methods of preventing moisture-vapour penetration at the seams. The finished products were submitted to test conditions designed to distinguish between packages whose differences were slight, since even small differences are

important in long storage; the packages were partially filled with anhydrous calcium chloride and stored in a special test room maintained at 80°F. and 85% relative humidity. The weighing was done right in the test room to record increases in moisture accurately.

A large number of packages was tested under these conditions. "Cellophane" films, when wax-coated or laminated to metal foil were the most satisfactory. Wax-coated cellophane was preferable to the barrier requiring metal, but some of the waxes used were too friable, particularly when stored at low temperatures and when subjected to fragility tests, such as dropping. It was observed that a number of short falls, a condition likely to be met in ordinary commercial handling and transport, caused greater damage to the water-vapour barrier than a single fall from a much greater height.

To overcome this brittlensss, extensive investigations were made of "flexible" waxes as coatings. The waxes when applied in thin layers provide a film that endures sharp folding and remains pliable over a wide range of temperatures. Another advantage is that they can be sealed to form a strong cohesive bond. Cellophane treated with these substances continued to have the most consistently low moisture-vapour permeability.

About six variations of the main types of package were selected for further test, this time with a foodstuff as filling material.

Dried Egg Packages

Since Canada was called upon to export thousands of tons of dried egg to Britain, it was necessary to develop suitable containers for this purpose. The bag-in-carton type of package seemed to offer several advantages; laboratory tests had shown wax-coated Cellophane to be a good moisture barrier and a bag made of this material reduced flexing difficulties to a minimum, the outer carton provided mechanical protection, facilities for manufacture were available, and the British authorities needed untreated kraft suitable for subsequent pulping. This and several other package types were used for large-scale shipping trials to Britain: these final tests showed the bag-in-carton type to be preferable, and provided data from which specifications were drawn for the packing of Canadian dried egg powder. This product is now packaged in two sizes of containers: 14 lb. net for restaurant use and 5 oz. (equivalent to a dozen eggs) for domestic use.

The large package consists of a moisture-vapour resistant liner bag inserted in a pure kraft paper bag, which is, in turn, inserted in a heavy kraft carton. Four such cartons are placed in a master shipping case. The liner is constructed from 450 M.S.Y.T. Cellophane coated with 40 lb. per ream of a commercially available, flexible-wax composition and formed into an envelope with the waxed surface inside; the bottom is folded and side seams are sealed. The top can be heat-sealed after filling and reclosures is possible by pressure sealing.

The small package is substantially similar in construction, but the liner bag is made from lighter Cellophane (300 M.S.Y.T.) and is inserted directly into the carton. After removing a portion of the contents the housewife can prevent undue moisture pick-up from the atmosphere of humid kitchens by resealing this package with her thumbnail.

Both packages are rectangular rather than cylindrical, since cylinders waste about 20% of the shipping space.

Dried Milk Packages

Dried milk powder must be protected from the oxygen in the air, since the latter causes deterioration of the butterfat fraction. This necessitates packaging in an inert gas or in vacuum, and although this is easily done in tin plate containers it is much more difficult to provide both a water-vapour barrier and an oxygen barrier in a package made from non-critical materials.

A wax-coated, laminated Cellophane package was much more permeable to carbon dioxide than to the oxygen or nitrogen of the air. When such a package is filled with carbon dioxide, this gas escapes very quickly and nitrogen of the air penetrate very slowly. When filled with a powdered dehydrated material and then carbon dioxide packed, the escaping gas causes the bag to be drawn tightly about the contents giving a vacuum-type pack with a hard, brick-like feel. Failures and leaks are readily detected by the package becoming soft again. Factory-scale trials have shown failures of not more than 2%.

The oxygen penetration into this package is still under test. Preliminary calculations, however, indicate that it might not reach dangerous levels within a year.

Apart from the protective value of this pack from the standpoint of oxygen penetration, the reduced pressure inside the package has a decided advantage since it overcomes the danger of opening seams or cracking the stock by the bellows action of alternating high and low pressures.

Mess Tin Ration Kits

Field trials with Army Mess Tin Ration kits showed that wax-coated Cellophane did not provide sufficient protection to the contents. A more suitable package was designed utilizing a wax-impregnated, wax-coated outer container. This provided reasonable protection at low temperatures and stood up well when subjected to rough handling. At the same time the packaging and arrangement of the individual items in the carton was considered, and many of them were redesigned.

Aircraft Food Container

A problem referred to us by the British Liaison Office, on behalf of the R.A.F. Ferry Command, involved designing a container that would keep foodstuffs or other materials from freezing during Transatlantic flight. Requirements included protection from temperatures as low as -20°F., minimum practicable bulk and weight, and freedom from fire hazards.

Tests were made first of available commercial containers, and it was found that it would be necessary to supply some heat, or increase the heat capacity of the container, if sandwiches were to be kept unfrozen for a period of 8 to 10 hours. Indications were that a current consumption of 10-20 watts would be adequate, and that this could be supplied from the generators of the aircraft.

The preliminary experiments showed that although bread in the centre of a large container did not reach the freezing range of 20° - 22°F. for 13 hours, the contents in the outer and intermediate regions were frozen in shorter layers was desirable.

The final container designed for the purpose weighed 17 lb. and carried 6 lb. of bread, equivalent to a tare:net ratio of 2.8:1.0. Insulation was provided with fire-resistant cotton batting held in place with plywood forms. Space for the heating lamp was provided at the bottom and space for circulation of air at the sides. The removable sandwich container was fitted with centre tube for air

circulation braced at the top with cross tubes. Handles were provided for carrying, and trunk catch closure for the lid.

This container was subjected to test at -40°F. with a heat input of 20 watts. After about 22 hours' exposure the lid was removed for 7 to 8 minutes, and this was repeated 2 hours later to simulate conditions of actual use. This naturally reduced the temperature for a time but after 72 hours' exposure the temperature of the bread was 40.4°F.

Packaging of Eviscerated Poultry

At the request of the Department of Agriculture, we undertook some work to determine possible methods for saving space in shipping poultry. By eviscerating and splitting the birds it was possible to reduce the shipping space by half. Attention was given to methods of protecting eviscerated surfaces during defrosting. Of these, coating the birds with Irish Moss containing 6% sodium chloride proved to be the most successful. The British authorities, however, felt that birds treated in this manner would not be acceptable in that country. Therefore further work has been held in abeyance.

Technical Enquiries

The development of moisture-vapour-resistant packages required the examination of a very large number of commercial materials. In most instances, the results of our tests were reported to companies who co-operated in furnishing materials. This frequently led to requests for further tests on specific items, and these were undertaken on a paid basis unless they fitted into our experimental program.

These early studies on the packaging of foodstuffs were later expanded to include the packaging of warlike stores for the Pacific theatre of operations.

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F. WORLD FOOD SUPPLIES

The world food position was naturally of direct interest to Canada. Since dehydration is one of the best methods for both concentrating a food product and reducing its perishability, during this period studies on egg dehydration were intensified, early work of a preliminary nature on the dehydration of pork was completed, and investigation of dried milk was undertaken.

EDIBLE FATS AND OILS

Canada is normally on an import basis for edible oils and fats. During the course of the war, imports from the Far East were cut off, and lack of transportation greatly reduced those from other sources. The acute shortage was met in part by increased hog production to provide bacon for Britain, which resulted in doubling the lard output. Flaxseed production was increased 10 times and the production of sunflowers, soybeans and rape was also substantially increased. However, lard and linseed oil were the only fatty materials produced in Canada in substantial quantities. Lard was a somewhat unsatisfactory substitute for vegetable oil shortenings because of its poor keeping quality, lack of blandness, and unsuitability for deep fat frying. It had however, two advantages: better shortening power and lower production cost. Linseed oil had not been used for edible purposes in Canada. When freshly deodorized, the shortening made from this material has little objectionable odour and taste. Its greatest drawback is that it soon reverts to painty odours and flavours that are even more pronounced after subjection to baking and frying temperatures.

The introduction of new oil seed crops would have required time, and could not solve the immediate problem. In 1942, therefore, requests for information and investigations were received from the Fats and Oils Administrator. With the co-operation of the Associate Committee on Grain Research, the situation was surveyed with respect to availability of commerical oil processing equipment and the best method of attacking the problems experimentally.

Vegetable Oils

A staff member of the Grain Research Laboratory was delegated to make a survey of the vegetable oil situation in Canada and the United States. Some time was spent in library work at Ottawa and visits were made to a number of firms

in both countries. A report was prepared containing general information on the existing vegetable oil situation on the North American continent crop prospects, and crushing capacity. It dealt with the utilization of flaxseed at some length and outlined proposals for research on this crop. In addition, suggestions were made for utilizing sunflowerseed, canning wastes and screenings.

Twenty thousand pounds of Giant Russian sunflowerseed was made available by the Department of Agriculture for experimental purposes. The Council made arrangements for several commercial firms to do the necessary processing experiments. Determinations were made of the oil and moisture content of the seed cake and of the peroxide and fatty acid content of the oils both here and in the Oil Seeds Laboratory of the Associate Committee on Grain Research at the University of Saskatchewan. The results were incorporated in recommendations for large scale treatment of sunflowerseed. The suitability of the sunflower product as a salad oil was examined at the request of the Department of Munitions and Supply. It was determined that sunflower oil was more susceptible to the development of rancidity than corn oil, but could be used where facilities were available for storage at reasonably low temperatures.

In co-operation with the Department of Agriculture the Grain Research Committee, and industrial firms, a number of other potential sources of vegetable oils were examined for processing characteristics and palatability. It was found that oils from the seeds of pumpkin, wild cucumber, mustard and a new type of soybean, 'Blackeye', developed at the Central Experimental Farm, could be used for the preparation of edible shortenings. From time to time, at the request of the Deputy Oils and Fats Administrator, Wartime Prices and Trades Board, a number of analyses were undertaken on samples of various oils offered to the Board. These included small-scale studies on oils from sunflowerseed, soya beans, Nigerian palm kernels, and skate fish. In addition, numerous technical inquiries relating to oils and fats were answered, including a request from the Department of National Defence for a literature review and report on the recovery of glycerine from the waste liquors of a soap factory.

Work at Ontario Research Foundation -- The Ontario Research Foundation which had already initiated experimental work on hydrogenated shortenings was asked to assist in investigations on the processing of linseed oil, with financial assistance from the National Research Council. Later, when the investi-

gations had passed through the preliminary stages, this Division agreed to examine linseed oil shortenings prepared at the O.R.F. for keeping quality characteristics, while the Cereal Division of the Central Experimental Farm volunteered to perform baking tests on the more promising products. Still later, as a result of independent experiments on adsorption refining of linseed oil, the Chemistry Department of Macdonald College entered the field, and agreed to study the efficacy of antioxidants in the stabilization of linseed shortening in addition to other aspects of the general problem. To co-ordinate these activities several informal meetings of investigators from the foregoing research institutions and from industrial concerns were necessary. In 1944, this group was formally organized as the Sub-Committee on Fats and Oils of the Canadian Committee on Food Preservation.

Reports from co-operating institutions on work completed to date are summarized as follows:

Linseed oil can be hydrogenated easily by procedures usually employed in the fat industries and with equipment of the type available in Canada, although it requires considerably more hydrogen than is required for the oils normally used. The resulting shortening is very resistant to the usual type of fat oxidation. The appearance and texture of baked goods made from freshly prepared shortening are also generally satisfactory. Unfortunately, however, the hydrogenated product is prone to flavour reversion which does not appear to be accompanied by easily detectable chemical changes in the fat. Evidence has been obtained from spectrophotometric analysis that the unpleasant odours and flavours that develop when linseed oil shortening is heated are due to the breakdown of an isomeric linoleic acid formed from linolenic acid during hydrogenation. This has been confirmed by experiments with concentrates of iso-linoleic acid.

The extent of flavour reversion was estimated by jury panels to determine stability under storage conditions and at baking or frying temperatures. Certain modifications in processing procedure such as the use of antioxidants, blends with other oils, high alkali concentrations in refining, and high temperatures of hydrogenation, were considered to retard but not to prevent the development of flavour reversion in the finished shortening. Modifications in other aspects of processing were without apparent effect. Various commercial linseed products examined were deemed to be unsatisfactory.

Animal Fats

Since Canada's principal source of edible fats was lard, work was undertaken to improve its stability and other characteristics with the hopes of obtaining a suitable alternative to vegetable oil shortenings. With the disappearance of pure vegetable oil shortenings, many types of oils were used for blending purposes. These mixed animal-vegetable shortenings were also examined. Before progress could be made in this field of investigation it was necessary to develop suitable analytical techniques, particularly for measuring the products of oxidative rancidity. Modifications were made on existing tests for aldehydes and carbonyl compounds. Analytical procedures are also being developed for use on other constituents such as linolenic, linoleic, and oleic acids. A co-operative study followed on the stability of various shortenings in army biscuits. The results of this work have been reported elsewhere. In association with the Department of Pensions and National Health consideration was also given to the question of adding non-toxic antioxidants to lard. Such additions are now permitted.

Survey of Commercial Lard -- Following preliminary storage studies, a survey was undertaken to obtain information on all types of lard produced in Canada. A questionnaire covering the details of lard production was sent to some 27 packers who provided information and samples of their products. All samples as received were assessed by the Swift stability test, and the samples subsequently stored at 80°F. Periodic examinations were made using peroxide oxygen, aldehyde, and carbonyl measurements and odour ratings. Other chemical and physical characteristics were also determined, including iodine value, saponification number, free fatty acid, linolenic, linoleic, oleic, and saturated acid contents, melting point, smoke point, refractive index and colour measurements. This work has shown that a short storage life is associated with a high initial aldehyde content as measured by the Kreis test. It was also found that the logarithms of Swift stability values were correlated with storage life to the extent of $r = .82$; and that peroxide oxygen and aldehyde contents were significantly associated. On the basis of this work it is believed that fresh lard should have an initial Kreis value of not greater than 5, zero peroxide oxygen content, and a minimum smoke point of 380 to 400°F.

The odour of the fresh lard was poor, only 4 of 34 samples being bland. The average storage life at 80°F. was 8 weeks, as assessed by odour ratings. The four bland samples had been produced by a dry rendering process,

and had been washed and deodorized before refining. Recommendations based on this survey were forwarded to all the packers who participated in the programme.

Army Salvage Fats -- Salvaged animal fats, including rendered fat from pork and beef trimmings, etc. were submitted by the Canadian Army Service Corps to determine their suitability for edible purposes. A number of the fats from stews and fried meats were considered too dark for edible use, and were referred to the Chemistry Division for evaluation of their soap-making possibilities. The remaining materials were examined for chemical characteristics, stability and culinary suitability. The Consumer Branch, Department of Agriculture, performed some of the baking tests. It was concluded that most of the fats submitted could be used for edible purposes without further treatment and that reasonably stable salvage fats could be prepared in Army kitchens if care were taken to avoid prolonged exposure of these products to air at high temperatures during rendering and clarifying. It was recommended that the fats be steam-rendered, rather than dry rendered, and that clarification of used fat be accomplished by heating the fat in contact with water.

DEHYDRATION OF MEAT

The Department of Scientific and Industrial Research of Great Britain brought to our attention the fact that the shipping situation and other factors might force Britain to import meat from Canada in the dehydrated form. Substantial amounts of dehydrated beef, mutton and some pork were being obtained from South America and Australia. Interest was shown by the Canadian Department of Agriculture and the various Canadian meat packers, with the result that investigational work was undertaken in the Division of Applied Biology.

Dried Pork

The best dried product resulted from cooking in an open steam-jacketed kettle, followed by mincing and tunnel-tray drying in 4 hours or less with a tray load of two pounds per square foot. Initial drying stage temperatures of 70° to 80°C. and final stage temperatures of 55° to 70°C. were satisfactory. Pork dried in this manner retained a high percentage of thiamin and had a palatability rating equal to that of the initial cooked material. A trial shipment of this product was forwarded to the Low Temperature Research Station at Cambridge. The report from this institution was favourable and indicated that if shipment of dried pork from Canada became necessary, the British people would be only too glad to

accept material of a quality similar to the sample. Fortunatley, while the shipping situation became serious, successful emergency measures made it unnecessary to export dehydrated pork from Canada.

Dehydrated pork was much more stable than other dehydrated products, e.g., dried eggs or dried milk. Storage for a year in tin plate containers at temperatures of 24° and 37°C. caused little decrease in palatability. Drying time, moisture content and storage temperature had little effect on keeping quality. Either vacuum-tray or tunnel-tray dried pork kept better than a drum-dried product. Reynold's metal A-10 was a satisfactory substitute for tin plate containers.

Dried Chicken

As a result of the increased egg production to meet wartime commitments, a large surplus of chicken and fowl developed on the Canadian market. The Department of Agriculture inquired whether chicken could be dehydrated to produce a palatable product. Preliminary trials indicated that chicken was more easily dehydrated than pork, and that the dehydrate was quite palatable. Tunnel-tray drying was a satisfactory method. Stored dehydrated chicken was less stable than dehydrated pork and rapidly became rancid. However, the surplus of chicken was consumed during meat rationing and commerical dehydration was unnecessary.

DRIED MILK

In wartime, dried milk becomes an almost essential dietary item when vast mobile military forces and displaced civilian populations must be fed. Questions regarding the estimation of quality in dried milk were brought up frequently in connection with the purchase of supplies for the Canadian Armed forces. It was also inevitable that Canada would be called upon to supply a large amount of this commodity, and an investigation was accordingly initiated on quality determinations, drying procedures, and storage characteristics.

Quality Tests

Before commencing investigation of the factors affecting the quality of dried milk, some consideration was given to methods of quality measurement. Material of widely varying quality was obtained from six producers of spray-dried whole milk powder. The samples were divided into sub-samples,

some of which were tested without further treatment, while others were assigned at random to a variety of storage conditions. These conditions were arranged to give different times of exposure to different temperatures at intervals of 25°F. from 32° to 140°F; to relative humidities of 16 and 85%; to atmospheres of air, nitrogen and carbon dioxide; and to bright sunlight.

The objective tests investigated were: oxygen and water sorption of the powders; chlorophyll and peroxide oxygen values of the fat; "browning" of the powder; fluorescence values, changes in peroxidase, trimethylamine, volatile sulphur compounds and diacetyl content; solubility by centrifuging and a potassium chloride solution method; titratable acidity; pH; congo rubin and iron numbers; foaming volume; coagulation by acid, alcohol and rennet; dielectric constant; colour intensity and colour quality; refractive index; viscosity and surface tension.

Some tests failed to give a satisfactory end-point and, for a number, the error in duplication was equal to or greater than the differences due to quality. Correlation coefficients of palatability with the remaining objective tests, i.e., peroxidase value, colour intensity, peroxide value, solubility index, colorimetric value, diacetyl value, fluorescence and titratable acidity, ranged from 0 to .47. The subjective measurement of palatability was finally adopted as the most precise measure of milk powder quality.

The Effect of Heat Treatment on Quality

For a number of years it has been considered advisable to cool milk powders to room temperature immediately on the completion of drying. Drum-dried powders cool rapidly to this temperature, while spray-dried powders are often left in the drier for long periods, and may be packed without cooling. Spray-dried powders packed without cooling have been observed to have temperatures of about 140°F. after 24 to 48 hours. Therefore some attention was given to effects of holding milk powders (a commercial and an experimental spray-dried whole milk and a commercial spray-dried skim milk) at high temperatures (80 to 140°F.) for a period of about a week. Quality changes were assessed by palatability scores. Powders stored at 100°F. for 7 days seemed to be preferable to powders stored at 80°, 120° or 140°F., verifying similar observations made on two previous occasions. These results indicated that 100°F. was the desirable temperature to which milk powder should be cooled. Current commercial practice permits this to be accomplished within a few minutes after the completion of drying.

The Effect of Light on Quality

Liquid milk is known to deteriorate rapidly as a result of exposure to light, but little information appeared to be available on the effect of light on dried milk powders. Skim milk powders and whole milk powders containing 26, 28 and 30% fat were stored exposed to sunlight and to artificial ultraviolet light, while similar samples were held in the dark at the same temperatures. Decrease in quality of whole milk powders was noted during exposure either to sunlight of ultraviolet light. It was calculated that for every eight hours' exposure to light, the powder decreased roughly 0.1 palatability unit. This was not serious, and light of the intensities used cannot be considered to have a marked effect unless the powder is exposed for long periods. Exposure to sunlight caused a marked decrease in the riboflavin content of all samples studied, the destruction being most pronounced in skim milk powders. The rate of destruction was greatest during the first 75 hours. The destruction of riboflavin in powders exposed to ultraviolet light was considerable although not as great as that caused by exposure to sunlight. Experimental evidence indicated that this was due to the lower energy of the ultraviolet lamp. Also, the wave lengths which cause maximum riboflavin destruction are not emitted by the ultraviolet source, but are found in the sun's spectrum.

Gas-Packing

During the course of a study on gas-packing of dried milk some evidence was obtained which would indicate that packing in carbon dioxide offered little protection to stored milk powders when quality was assessed by palatability. It was again noted here that samples stored at 100°F. were of better quality than samples stored at 80°F. Further work on gas-packing is under way.

Moisture Content

Palatability measurements were used as a measure of quality for whole and skim milk powders stored at a variety of temperatures and moisture contents. Little difference was found between whole milk powders of different fat levels (26-30%), although both whole and skim milk products from two plants differed markedly in stability. Storage temperatures above 60°F. promoted deterioration of powders. At all temperatures the skim milk powders showed an initial increase in palatability. A moisture content of 3% was preferable to 2 or 5%. The differences in stability between

powders from different plants were enhanced at the high moisture content and at the higher storage temperature.

Technical Assistance

Commercial firms and individuals have been assisted with analyses and advice, e.g., the analysis performed on samples of drum-dried powders submitted by Senator W.J. Hushion.

Dried Milk Shake Mix

Investigations at the Royal Victoria Hospital indicated that milk shakes, fed as a supplement to the regular hospital diet, were effective in reducing the time in bed ordinarily required for surgical cases. This result was reported at a meeting of the Associate Committee on Army Medical Research in November, 1944. This committee requested the Division of Applied Biology to undertake a study of the preparation and storage of dried mixes that would provide palatable milk shakes suitable for convalescent Army personnel in the European war theatre. Various mixtures of egg and milk were prepared, dehydrated, and subjected to storage treatment. In addition, dried mixes of whole and skim milk powders, and whole and skim powders with dehydrated egg were stored. The results indicated that the presence of egg either in the liquid mix or in the mixture of dehydrated products was unsatisfactory. It was recommended that the milk shake mix be prepared entirely from milk.

Studies having shown that the protein component was the fraction responsible for the beneficial effects, a partially skimmed milk product was recommended as the base for the dehydrated mix. This dried product had the following composition: fat, 14%; protein 31%; carbohydrate, 46%; ash, 6.9%; and moisture, 2.5%. On the basis of the investigations it was recommended that the product be gas-packed in tin plate containers for overseas shipment. A specification for this mix was prepared, based on the foregoing storage studies and other information available from the current experiments on dried whole milk powders.

The addition of flavourings to the mixture before dehydration would not be satisfactory since most of the flavourings are volatile and would be lost during the drying process. A study of flavourings to be used with the reconstituted mix indicated that chocolate, maple, vanilla, strawberry, and pineapple were all about equally acceptable. Chocolate and maple were slightly more desirable than the

other three. The amount of sucrose syrup to be used in the flavourings was also studied and laboratory evaluation of taster preference indicated that a commercial "triple strength" flavouring was the most desirable. This triple strength flavouring is made from syrup having a sugar content of 66% and containing 1½ times the amount of flavouring ordinarily present in the fountain syrup used in most cafes and soda bars.

About 7,000 lb. of dehydrated milk shake mix has been shipped for use by wounded Canadian Army personnel and another 10,000 is in production (June, 1945).

CHICK MORTALITY

Serious losses in the poultry industry were discussed at a conference held in Ottawa on January 1, 1944, following which the Department of Agriculture asked that the Division undertake work to determine causes of chick unthriftiness and mortality. It was thought that some of the physical factors involved in shipping chicks might be profitably investigated. It was also decided to investigate Salmonella as a contributing factor and to determine how this organism was being disseminated by the commercial chick hatcheries. Some 1,000 chicks were examined bacteriologically and less than 1% found to harbour S. pullorum. However in certain batches the percentage of infection reached 95. Most of the foregoing chicks were received from Ontario hatcheries. A few were obtained from the Western Provinces and in these pullorum was only found once, but another type of Salmonella (bareilly) was found in chicks from two hatcheries. Although investigations are not complete, it is possible that these organisms contribute to unthriftiness. This is the first positive evidence of these organisms in fowl, in Canada and this discovery provides a lead as to the source of Salmonella in egg powder. The effect of chilling on the subsequent growth rate of chicks was also considered. However, the chicks involved were not uniform enough to obtain definite conclusions, and this work is being continued.

MINOR PROBLEMS

Food Yeast

Interest in yeast as a source of supplementary protein and vitamins gave rise to a preliminary investigation of the effects of drying on the thiamin content of brewer's yeast. Later requests for information on debittered brewer's yeast and food yeast came from the Research Branch of the R.C.A.M.C. A literature survey was made and the results of

this search and Divisional investigations were made available to Army authorities. The British Department of Scientific and Industrial Research made available to us a culture of Torula utilus var. thermophila, with a request for information concerning Canadian work on food yeast. No substantial amount of work has ever been done on Torula in Canada. Although the Division did no experimental work on the organism, it was propagated in molasses in 10-gallon lots and cultures were supplied to the laboratories of the International Paper Company and to workers at the Experimental Farm.

Utilization of Fresh Water Fish

Early in 1943, the Planning Committee of the National Committee on Fish Culture asked for information on the possibilities of increasing fresh water fish procurement in Canada with the object of alleviating existing shortages of meat. Information obtained from government sources, universities and travel organizations indicated that the maximum catch, without depleting the basic fish stock, would be of the order of 123 million pounds per year, as compared with 83 million in 1941. In addition to this some 23 million pounds of so-called 'Coarse' fish would be available, providing modified food habits or improved processing would render them acceptable for human consumption.

"Egg Jams"

Dried egg powders are not altogether satisfactory for baking purposes. It was suggested that a mixture of egg liquid and sugar might be more suitable, and that the added sugar would act as a preservative during shipment. An egg: sugar ratio of one was required to avoid bacterial spoilage, but the mixture was susceptible to mould attack. Further additions of sugar did not solve the difficulty. However, pasteurization of the canned mixtures offers some promise.

Sanitation of Poultry-killing Plants

Great increase in poultry processing and high standards required by the military necessitated rigid control of poultry-killing plants. In co-operation with the Department of Agriculture, specifications were prepared for the construction, operation, and sanitation of these establishments.

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G. PACIFIC WAR

During this period the Division of Applied Biology received an increasing number of requests for information, particularly relating to the mould proofing of all types of materials being sent to the tropics. A meeting was called by the Directorate of Electrical and Communications Design of the Department of National Defence in October, 1943, at which representatives of the National Research Council and Department of Agriculture were present. Preliminary committees were organized and work suggested. Early in 1944, the need for tropicalization research became more pressing and the Council made a survey to assess what laboratory facilities were available to meet the requirements. Following this the Division initiated a project in this field.

In May of that year it became apparent that the scope of the work would have to be greatly expanded since a large number of service departments were involved. An interdepartmental Research and Development Policy Committee, War Against Japan was set up by the Department of National Defence. The work of this Committee was divided among several subcommittees, of which the Division had representation on the Canadian Packaging Committee, and the panel Committee on Acclimatization, Signals, Radar, and Optical Equipment. The Director was made a member of the main Development Policy Committee, War Against Japan. In addition to the Committee work reported below, numerous technical enquiries on all phases of tropicalization were dealt with.

TROPICALIZATION OF SERVICE EQUIPMENT

Contributions made by the Division to the solution of problems arising from the war in the Pacific area included study of methods of packaging and mould proofing of equipment, and provision of facilities for high and low temperature tests.

Packaging War-like Stores

Following the announcement that Canadian Armed Services were likely to participate in the war against Japan, the packaging investigations which had previously been concerned mainly with food were greatly expanded to include studies on packaging materials for all war-like stores intended for use in this theatre of operation. The new problems presented difficulties which were fundamentally different from those encountered in food packaging, where the

emphasis is placed upon the prevention of moisture adsorption, whereas with instruments and other items of Service equipment the accent is on prevention of corrosion and rotting. For certain delicate assemblies it is necessary to include a dessicant in the package.

When commencing this work some assumptions had to be made regarding the possible environmental conditions to which packages may be subjected. These were: storage on tropical beaches in emergency type shelters; storage in jungle regions; storage under hot arid conditions; transport through arctic regions, and transport by air. An attempt was made to simulate these conditions in the Laboratory by fixed or alternating temperature, humidity and pressure chambers.

The water-vapour transmission of packages under jungle conditions or beach storage was approximately the same. Any other treatment simulating additional storage or transport caused marked increases in the rate of water-vapour transmission during subsequent storage under humid conditions.

Several important features regarding the use of "Cellophane" as a packaging material were apparent. A flat seal appeared to be generally more desirable than a crimped seal, although the latter was more desirable if excessively high temperatures were to be expected. It was found that 300 MSYT Cellophane and triplex bags provided the greatest protection.

Of the materials studied, the most effective barriers were laminations of kraft to foil and Cellophane, or scrim to kraft and foil with a Butvar coating. Laminations utilizing kraft or metal foil produced water vapour barriers that were less likely to fracture when subjected to rough handling. Laminating the stocks produced a barrier with lower water-vapour transmission than was typical of either of the base sheets when used alone. Wax coatings effectively reduced water-vapour transmission but provided little added protection when the packages were subjected to shock. The water-vapour transmission of these materials after being stored in a cabinet which provided opportunity for optimum mould growth indicated that ageing during this storage period was a more severe factor in increasing water-vapour transmission than was the growth of moulds. Moulds seriously affected some materials, particularly glassine and some samples of kraft paper. This information was of value in designing packages for tropical

use and as an aid in the drafting of codes covering tropical packaging.

In addition to investigational work, a great deal of test work was done on a variety of packages used by various branches of the Armed Services. These included extended tests on equipment submitted by the Army Medical Corps, the Army Dental Service, Signals Division, Naval Services, the Inspection Board of the United Kingdom and Canada, the Canadian Packaging Committee, and others. Altogether some 27 detailed reports were issued on these subjects. Some of the test work requested by the Canadian Packaging Committee is detailed below as an example of the type of work done.

Testing for the Canadian Packaging Committee -- A current technique of packaging polished metal parts in an intimate wrap of grade C cloth was questioned during the preparation of packaging codes and specifications; an alternative suggestion was the use of a carton-overwrap. At the request of the Canadian Packaging Committee, these Laboratories in co-operation with the Ford Motor Company undertook a comparison of the two methods. Results to date have indicated that a carton-overwrap was the better method of packaging polished metal parts. On the basis of the work done it was recommended that metal parts having critical surfaces be treated with a good corrosion preventive, wrapped with a Grade A sheet, placed in a carton, the carton wrapped with Grade C material and sealed by dipping in wax.

An examination of ammunition tubes was requested. A comparison was accordingly made of tubes prepared from K.P. board with tubes prepared from chipboard plus K.P. board. These were examined for both water-vapour transmission and deformation. In general, no significant difference existed in the behaviour of the tubes and either type was believed suitable for the purpose intended. In a second test, six types of three inch T.M. bomb tubes were examined for dimensional stability only. It was observed that tubes prepared by a Hamilton company were most satisfactory. The three most desirable types were constructed as follows: 40 ln. impregnated kraft (outside), asphalt, 30-30-30 duplex kraft, asphalt, 0.019 chipboard immersed in asphalt, and finally chipboard; Irvington varnished coated stock (outside), asphalt, 30-30-30 duplex kraft, asphalt, 0.019 chipboard immersed in asphalt, and chipboard.

A box of Bren gun magazines which had been tropically packed at Longue Pointe Ordnance Depot was

submitted through the Canadian Packaging Committee by a member of the British Army Staff, with the request that the adequacy of the packaging be tested with regard to its ability to prevent corrosion. Testing was done under conditions simulating tropical storage on beaches. After one month, the contents were in good condition. Some cracking had occurred in the wax coating, and a little mould had grown on the impact packing. Although the package was satisfactory under these conditions, it was believed that it would fail under conditions of constant high humidity.

As a result of difficulties with packages for metal parts, high temperature testing of several types of packages from several sources was requested. Packages received from Ford, Chevrolet and Dodge were all wrapped in Grade C material and given a dip in microcrystalline wax, while packages from the Dodge company had also been given a second dipping in paraffin wax. In addition, some G. M. C. parts in Grade C wrap, dipped in microcrystalline wax and over-wrapped with waxed sulphite were included in the test. The results showed that a wax-dipped package using a type of wax similar to that on the Ford Motor Company packages or the application of an overwrap of waxed sulphite were far superior to the other methods of packaging.

Permalac, a vinyl polymer prepared by Chemical Coatings Limited, of Guelph, Ontario, was submitted to the Canadian Packaging Committee as a possible water resistant material. Tests of initial samples indicated that the material was not suitable for the purpose intended. Material submitted subsequently has however shown greater promise and is still under investigation in these Laboratories (1945).

Other controversial packaging techniques are also currently under investigation. These include methods of packaging brake linings, piston ring assemblies and hardware such as nuts and bolts. The Arctic Monopack Ration Kit, which is also designed for tropical use, is receiving attention.

During the course of drafting tentative codes for the Canadian Packaging Committee, assessment of the suitability of bend-test for determining the flexibility of waxes at low temperatures was tested. A currently used and relarively simple bend-test was compared with a pendulum method. The results indicated that the simple test was as suitable as the pendulum method, provided bending was done within a second or less. However, the pendulum method promises some differentiation in quality while the other test either passes or fails the sample. As a result of this work, use of the

simple method was continued. During the preparation of tentative code C.P.C. 111, a question arose regarding the suitability of a test for the deformation of laminated moisture vapour barriers. This test was studied in these Laboratories, found hard to interpret and accordingly deleted from the code.

The U.S. Army have made great advances in the tropical packaging of war material and their findings were given in the form of a course at the Forest Products Laboratories in Madison, Wisconsin. A member of this Division was sent down to attend the course. Upon return, he prepared a report summarising the work and this has been of great use both to the Division and to the C. P. C.

During the development of codes for tropical packaging it was observed that people doing the packaging seemed to know very little about the requirements and ultimate purposes of the package, and, therefore, worked carelessly. To bring packaging information to them, a humorous popular article on the topic was prepared for distribution throughout Canadian organizations concerned with tropical packaging.

The Preparation of Codes -- Divisional representatives on the Moisture and Corrosion Panel of the Canadian Packaging Committee have prepared a number of codes, participated in the development of other codes, and criticized codes for other panels. Concurrently, assistance was given in the preparation of lists of approved materials suitable for use under the various codes. Assistance was also given to the Paper and Paperboard Panel and to the Impact Packing Panel. Some of this work is listed in Table I.

TABLE I

PACKAGING CODES IN WHOSE DEVELOPMENT DIVISIONAL MEMBERS PARTICIPATED

Code No.	Subject	No. of pages
1	Wood, general	18
2	Nails and spikes	11
3	Screws, wood	6
4	Strapping, round, steel, coated	10
5	Strappinc, flat, steel	15
11	Boxes, wooden, nailed, export	36
13	Boxes, wooden, wirebound, export	19
14	Boxes, wooden, cleated, plywood, export	15
60	Adhesives, water resistant	6
101	Packaging procedure, methods I and IA	5
102	Corrosion prevention, methods of cleaning and drying	14
103	Corrosion prevention, materials and application	18
105	Wrapping greaseproof, materials for	9
107	Compound, sealing and dipping	6
108	Paper, overwrapping	3
110	Packaging procedure, method II	5
111	Barriers, moisture-vapour resistant	16
112	Desiccants, activated	8
115	Barriers, water-resistant, materials for	14
116	Barriers, water-resistant, adhesives for	5
117	Barriers, water-resistant, methods of application	18
118	Tape, pressure sensitive, water-resistant	6
251	General marking and identification for export	4

Signals Equipment

The present work was designed to assess the resistance of Service equipment to mould under tropical conditions. The procedures were resolved into three forms (1) hot humid-air exposures in a properly designed cabinet; (2) soil-burial; and (3) agar-plate tests. Each of these represented different conditions and served to bring out the peculiar properties of the materials under test. While each of the three test methods were in general use in several countries, the specific conditions surrounding their use were not clearly defined. Much work was required in the development of suitable testing cabinets, soil burial tests, and simplified laboratory procedures. Specifications were drawn for the agar-plate tests describing the nature and concentrations of necessary salts, species of moulds on specific materials and width of inhibition zone as a measure of fungicides for tropical use.

Communications equipment used in World War II has reached a high state of development, delicate apparatus being carried to forward positions in the battle front. The main problems to which this situation gives rise in tropical areas result from corrosion of delicate metal parts and deterioration of insulating materials. Metal parts are usually protected from water and water-vapour by varnishes and lacquers. A large number of these were tested and it was possible to select a number of appropriate materials for specific purposes.

The prevention of rotting, particularly by mould attack, required the study of many fungicides, limited however by the nature of the equipment. Mercurial fungicides could not be used in association with selenium rectifiers, while the use of copper fungicides was limited by their corrosive properties. Chlorinated phenols and other organic compounds seemed to have the greatest possibilities for general application to this type of equipment. The results of some of the test work on signals equipment are given below. To date (1945) this work has involved the compiling of some 41 technical reports.

Radio equipment -- At the request of the Directorate of Electrical and Communications Design, two complete wireless sets (Canadian) 11-58 mk I and one 19 mk II of Northern Electric manufacture were placed in a humidity cabinet at 90% + r. h. and 95°F. After one month, determinations were made of performance and extent of mould development. Reduction in transmitter output was 80% before cleaning the tubes and 40% after

cleaning. Audioamplifier output was reduced 35% and many other aspects of performance were affected. Mould development was particularly heavy on cotton-covered wires. Much less mould growth occurred on Irvolite tubing and no growth was obtained on wires covered with silk, varnished cambric or glass. Heavy mould growth also occurred on leather headgear straps, haversacks, audiotransformers and certain paper-covered condensers. Slight mould growth was evident on rubber and bakelite materials. Corrosion of exposed metal parts was common.

A further test was made with a treated wireless set (R.A.W. Receiver type No. 3284) which had been sprayed with a fungicidal lacquer obtained from Research Enterprises Limited, Toronto. After 1 month at 98-100% r.h., mould growth was clearly less on the components of this treated set than on the untreated sets tested previously. However, certain susceptible constituents supported medium to heavy mould growth. Spotty mould development occurred on the fabric diaphragm of receivers of radio headgear assemblies and on the rubber of plug-in terminals. Extensive mould development occurred on the apparently untreated portion of the fabric cover on cables, on chamois ear-pads, on the leather head-rest and in the interior of the microphone mouth-piece. Glue failure occurred between the chamois and the frame. Corrosion of the microphone capsules was extensive. Similarly a battery charger during 5 weeks under tropical conditions exhibited heavy moulding and corrosion of certain parts.

Four resistors and 3 capacitors were tested for mould resistance under accelerated conditions on an agar medium. The moulds used were those previously isolated from plastics and similar materials. The best results were obtained on resistors with ceramic coatings, relay coils with glass wrap covering or varnished cambric wrap, and transformer coils treated with Halo wax or Dulac 86A lacquer.

Microphone cables were tested for mould resistance of the component parts. The outer insulating materials, i.e., rubber tubing, glasswood filler, and glass-braid filler, under agar-plate test conditions individually supported heavy mould growth. On the glass such growths were initially rapid but soon subsided, while on the rubber-tubing the growths were initially slow but of long duration. Of the plastic materials and varnished tubings tested, all except Koroseal 2046 supported mould growth.

Lacquers and varnishes -- Lacquered fabrics surrounding the insulation on hook-up wires did not offer complete protection against the growth of Penicillium and Aspergillus species. The lacquer treatment offered complete protection against the cellulose-decomposing organism Chaetomium globosum. Dulac 86 varnish had little protective value for various radio components although slight mould-growth suppression was obtained. This varnish failed to adhere properly to certain components: blistering and peeling of the varnish was evident. Dulac fungus-resistant lacquers No. 96A (containing phenyl mercury salicylate) and 86A (containing pentachlorophenol), products of Maas and Waldstein, both conferred considerable mould resistance to the cotton braid of hook-up wires under all test conditions. Loss in effective mould resistance of braid treated with lacquer 96A was obtained in warm humid-air conditions (90-100% r.h. and 35°C.) which indicated the instability of phenyl mercury salicylate for use under tropical conditions. Lacquer 86A treatment maintained its fungus resistance property unimpaired.

Lacquers containing different fungus-proofing materials were applied to glass, cotton and wood surfaces. Good mould resistance under all test conditions was shown only by lacquer 86A (containing pentachlorophenol). Good mould resistance in air and agar plates but not in soil was shown by lacquer 3183B (containing Dowicide No. 6, a tetrachlorophenol). Lacquers C-98 and C-93 showed good mould resistance in humid air, but not under plate-test conditions. The remaining lacquers were poor in mould resistance.

Lacquers containing mercury concentrations from 0.0005-1.0% as phenyl mercury naphthanate were applied to paper strips and concentrations in excess of 0.05% metallic mercury were found necessary to impart complete mould resistance under all test conditions. In addition a large number of reputedly fungus-resistant, commercial lacquers and varnishes were tested and none was found to be entirely satisfactory under the test conditions used.

Batteries -- Tests of mould growth on batteries and battery packaging materials were undertaken for the Directorate of Electrical and Communications Design. The first set of batteries submitted deteriorated rapidly under high-humidity conditions and subsequently variations in design and impregnation were implemented. A variety of impregnating and surfacing materials for use in battery construction were also tested for mould resistance. Pentachlorophenol in suitable carriers (varnishes, lacquers or waxes) was effective in preventing mould development except under long-term exposure to

conditions conducive to excessive leaching or volatilization. Mercuric naphthenate and some other mercurial compounds were ineffective in protecting waxes from attack by fungi. A combination of treated lacquer and wax did not inhibit mould development.

Textiles

Tropicalization studies required a great expansion of the mould testing of textiles carried on in collaboration with the Textile Laboratory of the Division of Chemistry. Since fabric materials are likely to be worn or handled by Army personnel, certain fungicides toxic to humans are prohibited, or if used, must be used with discretion. Impregnated fabrics should retain their original physical qualities as far as possible. Extensive investigations were made on fungicides suitable for these purposes. In addition, many commercial preparations were subjected to test conditions at the request of various scientific and Service authorities. Some 17 technical reports were issued on the testing of textiles.

Since textiles are probably the most vulnerable of Service materials, the development of satisfactory rot-proofing treatment is highly important. Copper compounds have been widely used for the rot proofing of fabrics and of these copper naphthenate is one of the better agents now in use. Although oximes have been used to precipitate copper ions from aqueous solutions by analytical chemists, their possible use as agents for fixing copper in fabrics seems to have been overlooked, and as the basic materials for the preparation of a number of oximes were available as a result of work on the production of 2,3-butanediol it was thought worth-while to study this class of compound.

The first derivative studied as a copper fixative was dimethylglyoxime. Copper was fixed in jute, coarse cotton, and in woollen fabrics by dipping the test materials for two to five minutes in a 0.5% aqueous solution of dimethylglyoxime at 90° to 100°C, and then immersing them in 5% copper acetate at room temperature for 5 min. The amount of fixed copper was varied by altering the strength of the copper solution. The treated fabrics were odourless, remained pliable, and were dyed a khaki colour. Comparative soil burial tests showed that the copper fixed by dimethylglyoxime is superior to copper naphthenate as a rot-proofing agent, about one-quarter the amount of copper giving the same degree of protection. A sample of jute containing 1.5% copper fixed by dimethylglyoxime showed no loss in tensile

strength after five weeks' burial in soil in which an untreated sample was completely rotted in eight days. The interrelationships between concentration of copper acetate solution, volume of solution, quantity of duck being treated and the quantity of dimethylglyoxime in the duck have not been worked out, but copper must be present in excess quantities to yield satisfactory copper impregnations.

The use of other oximes and copper-precipitating compounds in the fixation of copper in Army duck is in an exploratory phase. The compounds include salicylaldoxime, -benzoinoxime, acetoin oxime, glucose oxime, fructose oxime, cupferron, rhodanine, s-diphenylcarbazide, diphenylthiocarbazone, 8-hydroxyquinoline, 1-nitroso-2-naphthol, dithio-oxamide, naphthenic and humic acids. The copper derivatives of these compounds produce a variety of colours on duck such as brown, green, purple, dark grey and blue. Many of the copper derivatives are quite resistant to acid and alkali conditions, in contrast to copper naphthenate and the copper precipitated by dimethylglyoxime, which are not. Preliminary agar-plate tests using pure cultures of certain fungi have also shown that these compounds have greater resistance to the bleaching effect of acid-producing nicro-organisms and to mould attack than either copper naphthenate or dimethylglyoxime. Experiments are now in pregress in which these compounds are being tested under the severe conditions of soil-burial.

General tests -- During the London blitz, some difficulty was experienced due to the moulding of fire hoses which rendered them useless. In answer to an enquiry on the subject, recommendations were made that helped to overcome the difficulty.

During the course of work in co-operation with the Division of Chemistry, it was found that iron-chrome dying of duck material, commonly used to produce a khaki colour, was of little or no value as a mould-inhibiting process. Treatment with copper or mercury compounds gave much better protection.

A request was received from the Chemical Warfare Establishment for investigation of mould deterioration of speech diaphragm materials. Initially three samples of cotton fabrics and one nylon-based sample were investigated. All were shown to support some mould growth. The three cotton fabrics had rotted after eight weeks' exposure

to high humidity conditions in air, but the nylon sample had retained its strength. In a later test the following diaphragm fabrics were tested in speaker assemblies: glass, Durafil, Tenasco, and nylon. All of these assemblies showed mould growth on the fabric. It was slight on nylon and most abundant on Tenasco, Aspergillus niger being the predominant organism. Fairly heavy surface mould (A. niger and Penicillium sp.) was observed on the lacquered glass surface. The fibres were bared in some spots as a result of the high humidity conditions. The Durafil showed dense mycelial growth imbedded in the fabric weave, but very little mould was visible on the surface.

Miscellaneous Chemical Warfare stores have been examined and many have been shown susceptible to decomposition or degradation as a result of mould activity. Treatments and replacements of defective supplies have been attempted with some measure of success. Rubber stoppers, for instance, stood up well to tropical conditions where cork plugs fell apart as a result of mould and high humidity. Of the sling materials tested in this project, a proofed sling by Kaufman's proved more resistant than standard issue slings. Rubber parts in general stood up very well to severe humidity conditions.

In two tests of cape materials, the heavily coated, cambric-based fabrics proved more resistant to cellulose-decomposers than most of the samples. A nylon-based fabric compounded with vinylite showed no loss of strength in soil half-burial tests, but under all high humidity conditions stiffened beyond use.

In a test requested by the R.C.A.F., it was found that the most readily moulded components of the oxygen mask assemblies were the canvas straps and cloth face-lining. The chamois face-lining was less readily affected, but eventually became fairly heavily moulded. The remaining (rubber) portions of the masks did not support extensive mould development and, for the most part, growth was superficial. Comparisons were made of growth obtained in the high-humidity room, and that observed on similar masks at the Panama tropical testing centre. Mould growth was parallel in these two sets of testing conditions.

Miscellaneous Service Materials

In addition to the foregoing, a number of tests were performed on such miscellaneous Service materials as paints, waxes, cements, treated woods and plywoods, recorder

papers, and insulation materials. This work was requested by Research Enterprises Limited; the Division of Chemistry, N.R.C.; the Department of Munitions and Supply; the Canadian Packaging Committee and the Army Medical Corps. Some 31 reports were issued on these subjects.

Of the paints tested, "Tygon" materials possessed some mould-inhibitory properties but were not entirely satisfactory. Fungicidal treatment applied to white and grey paints from Parker and Jones Ltd. was effective in reducing the number of mould species and the amount of growth, but even the untreated sample of white paint showed no development of moulds.

Five waxes from the Industrial Sands and Mineral Sales Corporation were tested and only one showed no mould development under all test conditions although a second wax possessed an intermediate degree of effectiveness. Johnson wax 5035 supported the development of moulds.

Of three types of Beaver Brand Cement tested, one was found to be excellent, and has since been used as a successful waterproof sealing compound for cardboard, cartons, etc. Four cements for use in automotive assemblies were shown to be completely resistant to mould attack.

Cherrywood treated with Permasan was given an intermediate degree of protection against moulds. Copper naphthenate impregnated spruce-wood showed no sign of moulds after 6 months' exposure to high humidities. Two types of plywood block (Luxite and Casophen) showed mould growth on the surface but no delamination or other deterioration. Of two types of pack-board, one fell apart after 2 months' exposure to high humidities; the other was laminated with urea-formaldehyde and retained its strength very well. Minor changes in design were advised to make the board more suitable for use in tropical climates.

Clean wet-strength map paper was quite resistant to mould attack in humid air. Ordinary and vinylite sprayed paper supported slight mould development of Aspergillus niger and Penicillium species, but all map papers when soiled supported abundant growths. Of a number of fungicides added to various papers, only "Milban" retained its mouldicidal properties through a wax lamination at 210° - 230°F. Incomplete protection was given to kraft paper by a wood filler known as "Wood-life".

A black thermal insulation material called "Isoflex", obtained from England, and recommended for use in house-type vehicle bodies, was found to possess excellent mould-resistant properties.

Facilities for Low Temperature Tests

The climate proofing of Service equipment also required a number of low temperature tests in addition to the tropicalization or high humidity tests referred to above. Use of refrigerated rooms associated with the food laboratories as test chambers has already been mentioned. As the war progressed the service ceiling of aircraft increased and the test temperature required for new equipment gradually decreased. The lowest temperature available was -40°F., and this was of little value where test temperatures of -70°F. were specified. Apart from aircraft instruments, the war in the colder regions and, in particular, the opening up of Canada's northlands by the Alaska Highway demanded low test temperatures for all types of Service and civilian equipment.

It is quite possible to obtain temperatures of -70°F. on a laboratory scale. These conditions could be provided on a temporary basis by the use of dry ice (carbon dioxide). They have also been obtained mechanically, but as a rule such equipment is manually operated and demands the services of an attendant during both the cooling period and the period of test. Production of these low temperatures for testing numerous or large pieces of equipment is, therefore, unsatisfactory because of the large amount of materials and delay involved in obtaining the specific test conditions.

By late 1943, the number of requests for tests in the low temperature field received by the National Research Laboratories made it evident that more satisfactory equipment for these tests should be provided. After full discussion it was agreed that a room of approximately 10' x 10' x 10' should be designed for working temperatures of -70°F. and that it should be cooled mechanically by automatic means. In this way, the required test facilities would be available to the entire staff of the Laboratories at all times and the tests completed with the minimum of delay. The Division of Applied Biology assumed the responsibility for designing, erecting and testing an automatic installation capable of meeting the above conditions.

Briefly, the installation consisted of a cascade system employing dichloro-difluoro-methane (F12) in the first stage and monochlor-difluoro-methane (F22) in the second stage. The latter refrigerant was a new one for which information on thermodynamic properties had just become available, and was chosen because it had a higher refrigerating effect and consequently greater efficiency at low temperatures. To overcome other difficulties associated with automatic installations at these low temperatures, the automatic installations at these low temperatures, the automatic control system was designed to modulate the speed of the compressors, in preference to the conventional on-and-off control. Even with the new refrigerant, the cooling coils would have operated under relatively high vacuum, which is comparatively useless for heat transfer. To overcome this difficulty, the liquid from the second stage was expanded into a plenum chamber and the resulting cold liquid formed on the removal of the flash gas pumped through the cooling coils. The small room to be held at -70°F. was adequately insulated and completely jacketted by another room held at about 0°F. with auxiliary equipment.

While the plans for this room were approved in 1943, the completion of details of design and difficulties in procuring the necessary specialized equipment delayed the installation considerably. It is now (1945) practically completed and, following initial tests, will be available for use. Apart from the need of this installation for testing Service equipment, it is of utmost importance for obtaining low temperatures necessary for the many test conditions required in an experimental institution.

CANNED BUTTER

The main problems involved in supplying foods for use in the tropics are not concerned so much with nutrition as with the prevention of deterioration. One of the most vulnerable items in the Service supplies is butter. Attempts to improve the keeping quality of canned butter in the Canadian Army Mess Tin Ration led to an investigation of the chemical and microbiological changes taking place in prints and canned butter stored at temperatures ranging from 30° to 90°F. A study was also made of objective methods of assessing deterioration.

Canned butter remained edible for more than 320 days at 30°F., 256 days at 50°F., 48 days at 70°F. and 16 days at 90°F. The prints lasted a much shorter time and adsorbed odours rapidly at 30°F. Deterioration was deter-

mined in the serum by means of a fluorescence test, pH measurements and formaldehyde titrations. A correlation coefficient of 0.84 was found between this fluorescence and flavour scores. The fat fraction remained apparently unchanged for much longer periods. Free fatty acids developed in appreciable amounts at the time the butter samples showed the greatest change in flavour. Peroxide oxygen and aldehyde values did not change appreciably. Bacteria and viable yeasts increased sharply in the butter at 90°F. and 70°F. during the first 4 days, then remained constant, while at 50°F. and 30°F. the increase was more gradual. Mould counts were higher for the prints throughout the storage life.

Australian operational experience indicated that a dehydrated butter substitute offered possibilities. In co-operation with Lever Brothers of Toronto, storage experiments on similar types of material were initiated. These experiments are still under way (1945) and, to date, spoilage has been evident after 16 days at 110°F. 48 days at 90°F. and 64 days at 70°F.

MINOR PROBLEMS

Japanese Rations

The internment of Japanese nationals brought up some difficult food problems. The Department of National Defence asked us to provide a suitable specification for curry powder for issue to Japanese prisoners. A study of all available literature on the subject revealed that curry powders were something like an Irish stew, the kinds and quantities of ingredient depending upon their availability and the whims of the cook. After consultation with the Spice Controller, it was possible to select eight spices obtainable in Canada from which a comparatively simple curry powder recipe was devised.

Through the courtesy of the U.S. Quartermaster Corps, samples of captured Japanese field rations were obtained for examination. They consisted of dried pickled prunes, dried fish mixtures and dried cereal mixtures, together with sugar blocks and a few other items--thoroughly revolting to Western tastes. The ration was carefully examined and when compared with the corresponding Canadian ration it was found to contain smaller quantities of all vitamins except riboflavin.

Sea Water Bacteria

The Department of National Defence, Naval Service, asked that samples of sea-water from a harbour be tested for organisms contributing to corrosion of steel hulls. The samples were found to contain from 0 to 4 sulphate reducing organisms per 100 ml. A sample of mud from the side of a ship was found to contain at least 100 sulphate reducers per 100 ml. Another sample of mud mixed with seaweed contained approximately 2,300 of these organisms per gram. Some rust-like material contained 5 to 6 per gram. Another muddy material was submitted to see if it might act as a corrosion preventative. It was decided that it would not since it contained 140,000,000 bacteria per gram and between 1,000 and 1,500 sulphate reducing organisms. Since organic matter was present it would probably be an excellent medium for the growth of reducing organisms.

Fibre Containers

Fibre containers having spirally wound bodies and metal ends were submitted for moisture penetration tests by the Research Department of the Continental Can Company. Samples of the two types submitted were partly filled with anhydrous calcium chloride, exposed to circulating air at 80°F. and 86% relative humidity, and weighed periodically to determine moisture gain. It was possible to distinguish between the two types.

Grease-Proof Wraps

The Ontario Research Foundation requested information on specifications for grease-proof papers for wrapping of shortening and butter. A search was made of the specifications from the United States and Britain, and a report prepared summarizing the available information.

Detonator Blocks

At the request of the Inspector of Propellants and Cartridges, Inspection Board of the United Kingdom and Canada, two types of detonator block were subjected to a climate test to determine their moisture adsorption under severe conditions. They were exposed to various humidities at 100°F. for storage periods of several weeks, resulting in a definite distinction in favour of a plastic block rather than the second type which appeared to be constructed of papier mache coated with wax.

Enclosed Spray Drying System

At the request of the Chemical Warfare Establishment, an enclosed spray drying system was designed; plans and sample calculations governing its use were provided.

Refrigerated Barges

Following the successful conversion of ordinary unrefrigerated cargo holds into refrigerated space to meet special emergency requirements, it was suggested that similar procedures might be valuable for the preservation of food-stuffs that are not sufficiently perishable to deteriorate under temperate climatic conditions but which deteriorate rapidly at tropical temperatures. An additional suggestion from the Chicago Quartermaster Depot, and the Office of the Quartermaster General, Washington, indicated that refrigerated barges, having a substantial capacity and fitted for maintaining cold storage temperatures, might be valuable for storing perishable foodstuffs in Pacific operational areas. There barges could be moved nearer to the theatre of operations as the fighting front advanced, problems of ship-to-shore transfer would be minimized, and by a suitable choice of barge size the craft could be moved up navigable rivers.

An application of refrigeration to this type of duty was outlined, and the equipment that would be available to meet these special needs, or might be provided within a reasonably short period. The requirements differed somewhat from those of previous applications of emergency refrigeration. Lower temperatures were needed, and had to be maintained over substantially longer periods, although it was possible to use much better insulation and more adequate power sources. The first of these refrigerated barges embodying a number of the suggestions put forward went into action early in 1945.

REPORTS

Tropicalization of Service Equipment

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Semeniok, G., Illman, W. I., Neish, A. C. and Ledingham, G. A. Comparative studies on various organic-copper fungicides for use in textiles. (In preparation).

Canned Butter

Grant, G. A. and White; W. H. A fluoremetric method for evaluating the keeping quality of salted butter (in preparation).

H. LAST DAYS OF THE WAR

The end of the war in Europe resulted in a general lowering of tempo, but this did not apply to the laboratory. To the biologist, V-E day meant continued effort to meet the needs of the Japanese war, to deal with the immense problems of feeding a devastated Europe, and to assess the new fields of investigation opened up by the war in relation to the national economy of the future.

Feeding Europe

The liberation of Europe means that at last it is possible to bring some relief to millions of starving victims of Nazi domination. Food processing, storage, and transport problems are therefore receiving increased attention. These problems have been of great importance ever since the war began, but the feeding of devastated Europe puts an even greater strain on all available facilities. While the shipping situation has improved considerably with the lifting of many restrictions imposed by war in the Atlantic, the tremendous demands for food and other supplies offset the advantages gained. Faster shipping schedules permit the shipment of more perishable goods to certain areas. In others, disrupted dock, terminal and inland transport facilities demand the maximum reduction in perishability and space. Research on these problems is essential.

Specific requests for aid on food problems have already been received, notably from U.N.R.R.A. Recently it was decided to supply the Jewish population of Europe with kosher meat products, and salami sausage was thought to be a suitable form for shipment. The sausage could not be canned since tin plate was still in short supply, and the Meat Board requested us to investigate the keeping quality of this product. Chemical and bacteriological examinations have been made and recommendations as to composition have already been forwarded to the Board. An experiment is in progress to determine the effects of temperature, relative humidity, and various methods of packaging on the storage life of this material.

National Economy of the Future

Investigational work must now be assessed in terms of its value in the national economy of the future. Obviously, many of the wartime discoveries and improvements can be applied to peacetime requirements. Several of the

principles used in the mergency refrigeration studies, for instance, may be of immense help in providing simple and efficient cold storage lockers during the post-war period. Indeed, many requests for information of this sort have already been received and some of these are detailed below.

Refrigerated Storage -- The Director of the Co-operative and Markets Branch, Ontario Department of Agriculture, and the Manager of Oxford Farm Co-operative Produce Co., Woodstock, visited the Division to discuss refrigeration problems in connection with a storage plant being constructed. The Division subsequently supplied further information and suggestions. Later, at the request of the Associate Editor of the Refrigerating Data Book, published by the American Society of Refrigerating Engineers, a chapter was prepared on refrigerated storage for conserving the palatability and nutritive value of dehydrated foods.

Emergency Rations for Aircraft -- Most of Canada lies in the Far North, and has yet to be developed. Projects such as the Alaska Highway will be of great assistance, but air transport is the best way of reaching many of these regions. The Department of Transport has requested advice on emergency rations for use in aircraft servicing the northern sections of Canada. These emergency rations must be low in weight, high in calories, and " not too attractive in order to avoid premature consumption". Suitable recommendations have been made.

Utilization of Crop Residues -- Enquiries received in the Division reveal that enthusiasts are prone to attribute a "Midas touch" to scientific studies on utilization of crop residues. During the war, our efforts to utilize these materials have been restricted to the production of products of immediate interest in the war effort. Interest can now be broadened to include a wider range of products of importance during years of peace. Present studies include the extraction of pentosans from straw, corn cobs, oat hulls, etc.; examination of the resinous constituents of milkweed and other plants and froth flotation of oil concentrates from grain screenings or low oil content seeds. In addition, many enquiries are being answered, ranging from the preparation of an article on the whole field of chemurgy for radio and magazine release through the Wartime Information Board, down to literature surveys on such specific items as the briquetting of straw.

Peacetime Committee Activities

During the war period, certain activities of a number of associate committees on which the Division is represented could not be suspended without loss of valuable material and essential information. However, committee work wherever possible was directed towards war problems, reported upon in a separate volume. Committee war work directly related to that of the Division has been mentioned throughout the present text. As soon as feasible, it is planned to resume peacetime projects on a scale more commensurate with their importance.

In 1944, the Council set up a Committee on Western Crop Investigations to deal with all financial problems related to western crops. This Committee is an amalgamation of the executives of the Associate Committee on Grain Research, the Associate Committee on Field Crop Diseases, and the former Associate Committee on Weeds. These committees have carried a number of projects on a maintainance basis connected with varietal tests on bread wheats, Durum wheats, barley, and other grains; root rot diseases of grains; and the bacteriology of soils and grains.

The Canadian Committee on Food Preservation is essentially a co-ordinating committee. It is divided into five sections; work on fruit, vegetables and fish is done by other government departments; Divisional representation on the fats and oils section has already been mentioned; the active work of the meat and poultry products section has been done almost entirely in this Division, and has already been described in previous sections of this report; considerable post-war work is planned by the Engineering Section.

The Associate Committee on Fish Culture and the Associate Committee on Parasitology are both connected with the Division, although no active work is done here. Long-term projects of the Subcommittee on Forest Tree Breeding of the Associate Committee on Forestry were continued, as they could not be abandoned without loss of valuable material; it is planned to expand this work in the post-war period.

LOOKING AHEAD

Looking beyond the immediate problem of feeding a devastated Europe, there are still many important problems to be solved in connection with perishable foods.

Wartime bacon cures are known to be too salty for the British palate. Reduction in salt content will increase perishability. This will demand construction of refrigerated docks at our ports and improved refrigerated shipping facilities. Dehydration of foodstuffs will likely be less important, but dried eggs and milk in particular will remain if processing methods are improved and quality maintained. Substantial progress has already been made in creating a post-war market for dried eggs. The work on fermentations should prove as valuable in peace as in war. Expansion rather than contraction of projects dealing with the utilization of agricultural wastes and surpluses is indicated.

The applied problems undertaken during the war have opened up a vast number of fundamental problems: the nature of the fluorescing substance found in many foodstuffs, the nutrition of organisms producing useful products by fermentation, the mechanism of these reactions, the nature of antibiotics, to mention only a few. A progressive national economy cannot afford unemployment or misemployment of scientific staff in our time.

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